(Frontispiece)

Reinforced concrete replica of the Athenian Parthenon at Nashville, Tenn.

CONCRETE PRACTICE

A TEXTBOOK FOR VOCATIONAL AND TRADE SCHOOLS

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PREFACE

The authors have attempted to present in this book such material as will be suitable to the needs of students in vocational courses and it is hoped that this material will also be of value to many men engaged in concrete work.

Attention is called to the exercises and problems accompanying practically all of the jobs throughout the text. It is thought that these will be of assistance in teaching the subjects treated in this book.

Laboratory and field equipment and the time available will usually not permit all of the jobs in the text to be assigned the student. The authors have included a large variety of jobs so that the instructor can select and use those which will be suitable.

G. A. Hool.
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Madison, Wisconsin
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CONTENTS

PAGE

PREFACE vii

SECTION I. FUNDAMENTAL CONSIDERATIONS

Composition and Knowledge of Concrete 1
Cementing Materials 2
Portland Cement 3
Manufacture of Portland Cement 4
Properties of Portland Cement 5
Portland Cement Mortars 7
Fine Aggregates 8
Coarse Aggregates 12
Water for Concrete Mixes 16
Properties of Concrete 17
Effects of Various Substances on Concrete 23

SECTION II. PROPORTIONING, MIXING, AND PLACING CONCRETE

Job 1. General Theory of Concrete Proportioning 26
Job 2. Proportioning Concrete by Arbitrary Proportions 28
Job 3. Proportioning Concrete with Reference to Voids 29
Job 4. Proportioning Concrete by Sieve Analyses of the Aggregates and the Maximum Density Curve 30
Job 5. Proportioning Concrete by the Surface Area Method 32
Job 6. Proportioning Concrete by the Use of the Tables in the 1924 Report of the Joint Committee 33
Job 7. Proportioning Concrete by the Water-cement Ratio and Slump Test 35
Job 8. Proportioning Concrete by the Water-cement Ratio, Slump, and Fineness Modulus of Aggregate 38
Job 9. Illustrative Example of Proportioning Concrete by the Water-cement Ratio, Slump, and Fineness Modulus of Aggregate . 43
Job 10. Consistency of Concrete 46
Job 11. Measuring Concrete Materials 48
Job 12. Computing Quantities of Materials for Concrete 49
Job 13. Hand Mixing of Concrete 51
Job 14. Machine Mixing of Concrete 55
Job 15. Concreting Plant 58
Job 16. Transportation of Concrete 61
Job 17. Depositing Concrete in Forms 66

PAGE
Job 18. Bonding New Concrete to Old 67
Job 19. Protection of Concrete when Hardening 68
Job 20. Placing Concrete Under Water 69
Job 21. Concreting during Freezing Weather 70
Job 22. Making Waterproof Concrete by Proper Proportioning of the Concrete Materials 73
Job 23. Waterproofing Concrete by Adding Integral Compounds . . . 74
Job 24. Waterproofing Concrete by Waterproof Coatings or Membranes 75
Job 25. Wooden Forms for Concrete 77
Job 26. Types of Wooden Forms for Concrete 81
Job 27. Metal Forms 91
Job 28. Removal of Form Marks and Mechanical Surface Finishing . 96
Job 29. Use of Colored Aggregates and Pigments 100
Job 30. Preparation of Wearing Surfaces 101
Job 31. Concrete Building Units 104
Job 32. Concrete Trim and Ornamental Stone 110

SECTION III. CONTRACTS, SPECIFICATIONS AND PLANS

Job 33. Contracts 115
Job 34. Standard Bridge Contract 116
Job 35. Specifications 120
Job 36. Standard Specifications for a Reinforced Concrete Highway Bridge 122
Job 37. Plans 137
Job 38. Standard Plans for a Reinforced Concrete Highway Bridge . . 139
Job 39. Plan Reading 139

SECTION IV. ESTIMATING

Job 40. Estimating in General 143
Job 41. Estimating Excavation 145
Job 42. Estimating Forms 151
Job 43. Estimating Concrete 154
Job 44. Estimating Steel for Reinforcement 158
Job 45. Estimating Finishing of Concrete Surfaces 161
Job 46. Estimating Miscellaneous Items 163
Job 47. Square and Cube Methods of Estimating Building Costs . . . 166
Job 48. Sample Quantity Estimate of Concrete Work 168
Job 49. Sample Cost Estimate of Concrete Work 172
Job 50. Time and Work Schedules for Concrete Jobs 173
Job 51. Progress Reports and Charts 175

SECTION V. LABORATORY METHODS

Work in the Laboratory 180
Laboratory Reports 181
Job 52. Inspection and Sampling of Portland Cement 183
Job 53. Normal Consistency of Portland Cement 184

		Page
Job 54.	Time of Setting of Portland Cement	185
Job 55.	Soundness Test of Portland Cement	186
Job 56.	Standard Tension Test	186
Job 57.	Fineness of Portland Cement	187
Job 58.	Inspection and Sampling of Aggregates	188
Job 59.	Unit Weight of Concrete Aggregates	189
Job 60.	Sieve Analyses of Aggregates	190
Job 61.	Sieve Analysis Curves	191
Job 62.	Voids in Fine and Coarse Aggregates	191
Job 63.	Silt in Fine Aggregate	193
Job 64.	Colorimetric Test of a Fine Aggregate	194
Job 65.	Bulking Effect of Water in Sand	195
Job 66.	Tensile Strength of Cement Mortars Made with Different Sands	196
Job 67.	Tensile Strength of Cement Mortars of Different Proportions	196
Job 68.	Consistency of Portland Cement Concrete	198
Job 69.	Proportioning Concrete by Arbitrary Proportions	199
Job 70.	Proportioning Concrete by the Use of the Tables of the 1924 Joint Committee Report	200
Job 71.	Proportioning Concrete by the Water-cement Ratio and Slump Test	202
Job 72.	Proportioning Concrete by the Water-cement Ratio, Slump, and Fineness Modulus of Aggregate	204
Job 73.	Effect of Varying the Amount of Mixing Water in a Given Mix	205
Job 74.	Effect of Varying the Fineness Modulus of the Aggregate on the Economy of the Mix	207
Job 75.	Effect of Varying the Fineness Modulus of the Aggregate upon the Slump, and upon the Water-cement Ratio Required for a Given Slump	208
Job 76.	Effect of Age on the Compressive Strength of Concrete	211
Job 77.	Tests Required for Concrete Materials	212
Job 78.	Testing Machines Used in Testing Concrete and Concrete Materials	213

Section VI. Field Work

	Inspection of Concrete Work	218
	Supervision of Concrete Work	220
Job 79.	Concrete Basement—Staking Out	223
Job 80.	Concrete Basement—Estimating	225
Job 81.	Concrete Basement—Excavation	227
Job 82.	Concrete Basement—Forming	229
Job 83.	Concrete Basement—Concreting	231
Job 84.	Concrete Basement—Removal of Forms	232
Job 85.	Concrete Sidewalks—Specifications and Estimates	233
Job 86.	Concrete Sidewalks—Location, Grade, Base, and Forms	234

PAGE
Job 87. Concrete Sidewalks—Concreting, Finishing, and Curing . . . 236
Job 88. Concrete Curbs and Gutters 241
Job 89. Concrete Pavements—Design, Specifications, and Estimates . 245
Job 90. Concrete Pavements—Subgrade and Forms. 251
Job 91. Concrete Pavements—Concrete Plant and Organization of Crew. 252
Job 92. Concrete Pavements—Proportioning, Mixing, Placing, and Finishing Concrete. 255
Job 93. Concrete Pavements—Curing. 259
Job 94. Concrete Septic Tanks. 263
Job 95. Concrete Steps 267
Job 96. Concrete Window Sills and Lintels. 269
Job 97. Plain Concrete Floors 271
Job 98. Concrete Culverts—Specifications and Estimates 275
Job 99. Concrete Box Culverts—Excavation and Staking Out . . . 280
Job 100. Concrete Box Culverts—Forms and Reinforcement. 281
Job 101. Concrete Box Culverts—Concreting. 282
Job 102. Concrete Box Culverts—Removing Forms. 283
Job 103. Construction of Reinforced Concrete Buildings. 283
Job 104. Construction of Reinforced Concrete Slab and Girder Bridges 289
Job 105. Construction of Reinforced Concrete Arch Bridges 293
Job 106. Manufacture of Concrete Block or Brick 298
Job 107. Laying Concrete Block Walls 299

Section VII. Appendices

No. 1. Standard Specifications and Tests for Portland Cement, A.S.T.M., C9 21. 303
No. 2. Standard Method of Test for Unit Weight of Aggregate for Concrete, A.S.T.M., C29–21 319
No. 3. Standard Method of Test for Sieve Analysis of Aggregates for Concrete, A.S.T.M., C41–24 320
No. 4. Tentative Method of Decantation Test for Sand and Other Fine Aggregates, A.S.T.M., D136–22T. 322
No. 5. Standard Methods of Test for Organic Impurities in Sands for Concrete, A.S.T.M., C40–22 323
No. 6. Proportions for Concrete of Given Compressive Strength at 28 Days, 1924 Report of the Joint Committee. 324
No. 7. Tentative Method of Test for Consistency of Portland Cement Concrete, A.S.T.M., D138–25T. 329
No. 8. Standard Methods of Making Compression Tests of Concrete, A.S.T.M., C39–25. 330
No. 9. Standard Methods of Making and Storing Specimens of Concrete in the Field, A.S.T.M., C31–21 335
No. 10. Effect of Oils and Miscellaneous Liquids on Concrete and Method of Protective Treatment Where Required. 339

PAGE
No. 11. Standard Specifications for Concrete Building Block and Concrete Building Tile, A.C.I., P–1A–25. 342
No. 12. Standard Specifications for Concrete Brick, A.C.I., P-1B 25 . 344
No. 13. Specifications for Portland Cement Concrete Pavement for Highways, A.C.I 346

INDEX. 363

CONCRETE PRACTICE

SECTION I

FUNDAMENTAL CONSIDERATIONS

COMPOSITION AND KNOWLEDGE OF CONCRETE

Concrete is an artificial stone made by mixing, in the proper proportions, cement, water, and an aggregate consisting of large and small particles.

The cement, which is the binding material in the concrete, should preferably be a portland cement that has passed the standard specifications and tests (Appendix 1).

The water should be clean and free from any impurities which would be injurious to the concrete.

The aggregates are the inert materials in the concrete, such as broken stone, gravel, sand, cinders, screenings, etc. There are two classes of aggregates, fine and coarse. A fine aggregate is usually defined as the material *passing* a No. 4 sieve, and a coarse aggregate as the material *held on* (not passing) a No. 4 sieve. This sieve is one having four meshes per lineal inch. The aggregates should be of such materials, sizes, and grading as will be suitable for the concrete work contemplated.

To obtain quality concrete, it is necessary to use good materials, to have the concrete mix correctly proportioned, the batch thoroughly mixed and carefully placed in the forms, and then the concrete allowed to harden under suitable curing conditions.

It is evident that a comparatively extensive knowledge is required, based on study and experience, before good concrete can be made consistently. A vast fund of information concerning concrete and concrete materials has been obtained, and made available for use through the efforts of cement manufacturers,

various associations and societies (especially the Portland Cement Association and the American Concrete Institute), testing laboratories, and a large number of consulting engineers. The concrete industry, however, even considering the large amount of concrete now made each year, is yet in its infancy, and many facts concerning concrete are still undiscovered.

CEMENTING MATERIALS

Cementing materials may be classified as follows:

Non-hydraulic:	Hydraulic:
Gypsum plasters	Hydraulic lime
Common lime	Puzzolan or slag cement
	Natural cement
	Portland cement
	Quick-hardening cements

Hydraulic cements will set under water, which is not true of non-hydraulic cements.

Gypsum plasters are produced by the partial or complete dehydration (dewatering) of gypsum. Plaster of Paris is a partially dehydrated gypsum.

Common lime is made by burning a comparatively pure limestone at a low temperature. It will slake when mixed with water, but will not set under water.

Hydraulic lime is made by burning a slightly argillaceous limestone at a low temperature. It will slake slowly, and will set very slowly under water.

Puzzolanic or slag cement is made by mixing slaked lime with natural puzzolanic materials, or with granulated blast-furnace slag. This cement will not slake, but it has hydraulic properties when ground.

Natural cement is made by burning an argillaceous limestone (limestone containing clay) at a comparatively high temperature. It will not slake, but, when ground, has hydraulic properties.

Portland cement is made by burning an artificial mixture of argillaceous and calcareous materials to the high temperature of incipient fusion, and then finely grinding the clinker. Portland cement will not slake, but it has very marked hydraulic properties when finely ground.

Most of the so-called quick-hardening cements are made in about the same manner as portland cement, except that different proportions and kinds of raw materials are used. These cements, in general, are very similar to portland cement in their properties, except that they will harden and obtain their strength much more rapidly.

PORTLAND CEMENT

Portland cement, the most important of all of the cementing materials at the present time, is defined as the product obtained by finely pulverizing clinker, produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

The principles of making a hydraulic cement were discovered in the year 1756, by John Smeaton of England, but he did not carry his investigations far enough, and it was left for another man really to start the portland cement industry. This man was Joseph Aspdin, a bricklayer in the town of Leeds, England. As a result of his experiments, Mr. Aspdin was able, in the latter part of 1824, to obtain a patent for a superior kind of cement. This cement he called "portland" cement, because of its resemblance to the building stone obtained from the island of Portland.

Joseph Aspdin erected his first portland cement plant in Wakefield, and, after overcoming many difficulties, was able to produce his cement on a commercial scale. He was assisted in his work by his sons, William and James. William Aspdin made several improvements in the process of manufacture, and later, in 1854, went to Germany and established three plants in that country.

During the period 1840 to 1860 several other portland cement plants were started, and the new industry had a slow but sure growth. This slow growth was due mainly to the increasing use of Roman cement, a natural cement invented by James Parker, in 1791. It was not until about 1865, that portland cement superseded its rival, Roman cement, in the construction field in England.

In later years, the invention and perfection of rotary kilns, ball and tube mills, and other machinery did much to improve the quality of the cement and to reduce the cost of manufacture.

Although natural cement was first manufactured in the United States in about 1820, it was not until 1872 that David O. Saylor

began his investigations with portland cement. From that time until about 1900, the growth of the portland cement industry in the United States was comparatively slow. Even as late as 1894, there were only about twenty portland cement plants in this country, producing about 800,000 bbl. of cement annually, while the annual production of natural cement at that time was about 8,000,000 bbl.

Since about 1900, further discoveries of suitable raw materials throughout the country, improvements in manufacturing machinery and processes, and the resultant reductions in costs have tended rapidly to increase the use of portland cement so that the United States now surpasses the rest of the world in the production and use of this material.

Today, the American portland cement industry has about 140 plants employing approximately 40,000 men, and producing about 150,000,000 bbl. of cement annually. Portland cement of good quality is now available in all parts of this country at fairly reasonable prices.

The wonderful growth of the portland cement industry has been mostly due to the systematic development and improvement of efficient grinding machinery, rotary kilns, chemical control during manufacture, standard specifications, and the various uses of portland cement.

Portland cement now ranks next to steel and timber as a structural material, and it may outrank timber in the near future.

MANUFACTURE OF PORTLAND CEMENT

The raw materials generally used in the manufacture of portland cement are those listed in the following table:

RAW MATERIALS FOR PORTLAND CEMENT MANUFACTURE

Argillaceous materials	Calcareous materials
Argillaceous limestone	Pure limestone
Clay or shale	Pure limestone
Clay or shale	Marl
Blast furnace slag	Pure limestone
Clay or shale	Chalk or chalky limestone
Clay or shale	Alkali waste

Many of these materials are obtained by quarrying, after which they are conveyed to powerful crushers, and broken up into small sizes suitable for the grinders. In the dry process, the crushed materials are dried, mixed in the correct proportions, and then ground in mills to a powder, so that about 95 per cent of the materials will pass a 100-mesh sieve. These finely ground materials pass into a large rotary kiln, where they are burned to a clinker at a maximum temperature of about 3000°F. After the clinker has been sprayed with water and cooled, a retarder (usually gypsum) is added, and the material is then finely ground in mills, so that 78 per cent or more will pass a standard 200-mesh sieve. The cement is now conveyed to a storage bin for seasoning.

In the wet process of manufacture, the materials are usually ground when wet, after which they are mixed in the correct proportions and enough water added to make a thin mud or slurry. The mixing is done in a pug mill. This slurry is pumped to a vat, where a chemical analysis is made, and the proportions corrected when necessary. From the vats, the slurry is conveyed to a special type of rotary kiln in which it is burned.

After the clinker is removed from the kiln, the remaining part of the wet process of manufacture is similar to that of the dry process.

The wet process permits of better chemical control and easier grinding than the dry process does, but requires a little more fuel for burning.

After being seasoned in storage bins for a few weeks, the cement is usually packed in sacks holding 94 lb., or in barrels holding 376 lb., and made ready for shipment. Sometimes the cement is shipped by bulk in railway cars.

When portland cement is stored under ordinary conditions, it is apt to deteriorate. Consequently, cement that has been stored for more than a few weeks should be retested before being used in important concrete work. If, however, the cement is stored so that it is protected from moisture and carbon dioxide in the air, it may be kept indefinitely without loss of strength.

PROPERTIES OF PORTLAND CEMENT

Portland cement is a valuable structural material, because it has strength and soundness after hardening. In order to com-

pare different portland cements as to their qualities, and to determine their suitability for use, it is necessary to make certain standardized tests on the cements, and to observe if they pass certain standard specifications. (See Appendix 1 for the Standard Specifications and Tests for Portland Cement.)

The most important quality of portland cement is soundness. It is not desirable to use a cement for structural purposes, if that cement will later disintegrate and crumble and cause a failure of the structure. Unsoundness is usually shown by expansion after the cement has set, followed by disintegration. Free lime in the cement is the most common cause of unsoundness. The steam test (accelerated test) is valuable for determining the soundness of a portland cement.

The next quality, in order of structural importance, is strength. The compressive strength of a cement, when made into a mortar or a concrete, is the best criterion to use, but, because the tensile test was easier to standardize and apply, the tensile strength of a 1:3 mortar, made of a portland cement and the standard Ottawa sand, has been selected as a means of comparing different portland cements and also for determining their suitability for use. The tensile strength of neat portland cement is about 600 lb. per sq. in., or more, at an age of 28 days, while the neat compressive strength is about ten times this value. The shearing strength is about the same as the tensile strength. Finer grinding of the cement will increase the strength of the mortar, but not of the neat cement.

The time of set is important, in that the cement should obtain its initial set slowly enough so that there will be ample time first to place the mortar or concrete in the forms. Too long a time should not be required for the hard set, or the progress of the work may be delayed. In general, warm or dry weather will shorten the time required for setting, while an excess of water will lengthen it. An addition of gypsum or plaster of Paris up to about 3 per cent by weight will retard the time of set, while a larger addition of plaster of Paris may give the cement a "flash" set.

Fineness of grinding is important, as the finer particles of the cement determine its cementing values. Fine grinding increases the strength of cement mortars, increases the sand-carrying

capacity, decreases the time of set, and seems to make the cement more sound.

The test for specific gravity is usually not made unless specifically ordered. This test is sometimes useful for determining possible adulterations of the cement.

The specifications require, in regard to the chemical properties of portland cement, that certain limits be not exceeded. Chemical tests are not often made on a commercial sample, unless this sample should fail to pass the physical tests.

Exercises.—What are the specification limits for tensile strength? For time of set? For fineness?

Would a portland cement be considered suitable for use in concrete work, if the test results were as follows:

Chemical properties—satisfactory.

Specific gravity—3.12.

Percentage passing the standard 200-mesh sieve—79 per cent.

Soundness—pat remained hard and firm and showed no signs of distortion, checking, cracking, or disintegration.

Tensile strength of 1:3 standard sand mortar—at 7 days = 328 lb. per sq. in.; and at 28 days = 316 lb. per sq. in.

PORTLAND CEMENT MORTARS

A portland cement mortar is a mixture of portland cement, water, and a fine aggregate (sand or its equivalent). The portland cement should be one capable of passing the standard specifications (Appendix 1). The water should be clean and free from any impurities which would be injurious to the mortar. The requirements for fine aggregate are given in the next article.

The mortar may be proportioned by weight or by volume. Proportioning by weight is the better method, and is used to a large extent in laboratories, while proportioning by volume is generally used on the job. If the sand is wet, the proportions should be corrected for the water present. When measuring wet sand by volume, the bulking effect of the water may be quite large, and this effect should be determined and allowance made.

The mortar may be mixed either by hand or by machine. Machine mixing is faster, and the quality is more uniform than in hand mixing. The batches should not be too large. The cement and sand should be mixed dry, the water added, and the batch mixed again. Thorough mixing is essential.

The mortar should be used before the initial set has occurred. Retempering (remixing) of a portland cement mortar should not be permitted after the initial set has taken place.

In general, the strength of a portland cement mortar depends upon the proportion of the cement, the amount of the mixing water, and the size and grading of the sand. Other things being equal, increasing the proportion of cement increases the strength, while increasing the amount of water decreases the strength and lengthens the time of set. Just sufficient water should be used to give a workable mix. In regard to the sand, test results show that the densest sand usually makes the strongest mortar, that the proportion of fine sand should be small, and that coarse sand makes a stronger mortar than fine sand.

The tensile strength of a 1:3 mortar made with a good sand should be equal to, or more than, 200 lb. per sq. in. at an age of 7 days, and equal to, or more than, 300 lb. per sq. in. at an age of 28 days.

The compressive strength of a good 1:3 mortar should be 1200 lb. per sq. in. or more at an age of 7 days, and 2000 lb. per sq. in. or more at an age of 28 days.

The transverse (cross-bending) strength is approximately twice the tensile strength.

The adhesive strength depends upon the materials to which the mortar is attached, but is never more than the tensile strength of the mortar.

The weight of a good portland cement mortar of a 1:1 mix is about 145 lb. per cu. ft.; of a 1:3 mix about 140 lb. per cu. ft.; and of a 1:4 mix about 138 lb. per cu. ft.

Exercises.—Which method of proportioning mortar is the better? Why? What is the effect of using too much mixing water?

On what does the strength of a portland cement mortar depend?

FINE AGGREGATES

Sand of some kind is found in practically every locality of the United States. Most of the sands are suitable for use in concrete, especially after they have been washed to remove clay and dirt, and have been screened to remove particles that are too large. Sometimes a sand is found that is not suitable for use in concrete,

in which case another sand should be procured, even if it must be shipped in from some other locality.

Visual inspection of a source of supply is an aid in determining the qualities of a sand. The mineral constituents may be identified, the uniformity of supply and of grading approximately determined, and the presence of silt (either free or adhering to the grains) may be noted. A rough test for the presence of silt may be made by rubbing a small amount of the sand in the palm of the hand, and observing if the palm is stained. A stain denotes the presence of silt.

The best sand for concrete work, as to grading, is one which contains both coarse and fine grains in such proportions that the percentage of voids will be a minimum. A coarse-grained sand is better than a fine-grained one. Impurities, such as those mentioned in the specifications which follow, should not be present, as they may make the sand worthless for concrete purposes. A small percentage of finely divided clay or loam is not usually injurious.

The percentage of voids in a sand usually ranges from 25 to 45 per cent. The weight per cubic foot varies from about 85 to 120 lb. for dry sands tested according to the method in Appendix 2. The weight per cubic foot of loose sand may be as much as 20 per cent less than that of the same sand compacted by rodding. Moist sand weighs less than dry sand. The percentage of absorption of a sand rarely exceeds 3 per cent. The specific gravity of sand usually varies from 2.6 to 2.7 with an average value of 2.65.

The bulking effect of water in sand should be allowed for when measuring wet sand by volume. When water is added to a sand, it wets the surface of the grains, forming a film of water around each particle, as well as tending to fill the voids. This surface film forces the grains of sand apart and causes bulking, the amount of the bulking depending upon the amount of water present and the fineness of the sand. The bulking effect increases with the surface area of the sand. The maximum bulking effect usually occurs with about 5 or 6 per cent of water by weight. The maximum amount of bulking varies with different sands; in fine sand it may be as great as 30 per cent; in medium sand, 25 per cent; and in coarse sand, 20 per cent. The addition of from 1 to 2 per cent of water by weight may increase the volume from

10 to 20 per cent in some instances. When from 16 to 20 per cent of water is added, the sand becomes completely flooded or inundated, and its volume becomes nearly the same (often a few per cent more) as that of the dry sand. The inundating of a sand overcomes the bulking effect and, when a sand is measured in a completely immersed condition, its volume is practically the same as that of the same sand in a dry condition. These values are for a sand which has been fairly well tamped. The bulking effect on a loose sand would probably be from 30 to 50 per cent more than the values given.

The sieve analysis test of a sand, as described in Appendix 3, is one of the best tests for determining the suitability of the sand as

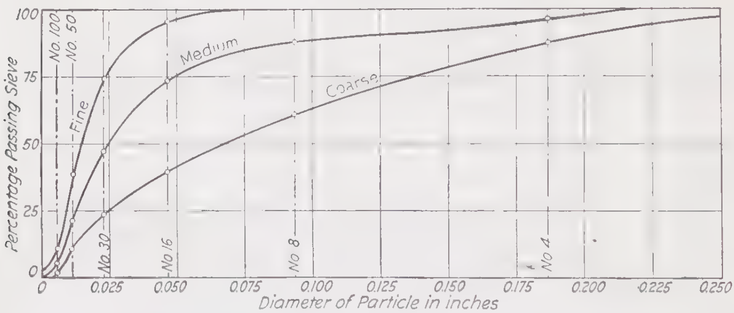


FIG. 1.—Typical mechanical analyses of fine, medium, and coarse sands.

a concrete aggregate. The results of a sieve analysis may be plotted as in Fig. 1, and the comparative grading determined at a glance. This figure shows typical sieve analysis curves for fine, medium, and coarse sands.

The fineness modulus for a fine aggregate is equal to one-one hundredth of the sum of the percentages by weight of this aggregate *retained on* (*coarser than*) the following standard square mesh sieves: Nos. 4, 8, 16, 30, 50, and 100. The 3/8-in. sieve should be included when sieving coarse sands. (Refer to Appendix 3 for sizes of sieve openings and wire diameters.) A fine aggregate, having a fineness modulus of from about 2 to 3.60, is considered suitable for concrete work.

For a description of the standard Ottawa sand used in the testing of portland cement, see Sec. 50 of Appendix 1. The

percentage of voids in this sand is about 37 and the weight per cubic foot is about 104 lb.

Stone screenings, the fine material that has been screened out of crushed stone, may be a good, fine aggregate for concrete, when free from clay and dirt. Stone screenings may be a little coarser than an average sand, but they have about the same percentage of voids and weight per cubic foot.

The following specifications for fine aggregate for concrete are taken almost verbatim from the 1924 *Report* of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete.

Specifications for Fine Aggregate for Concrete.—Fine aggregate for concrete shall consist of sand or other approved inert materials of similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains, and free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam, or other deleterious substances.

The fine aggregate shall range in size from fine to coarse particles within the limits given in the following table:

Grading of Fine Aggregate

	Per Cent by Weight
Passing No. 4 sieve	Not less than 85
Passing No. 50 sieve	Not more than 30 and not less than 10
Weight removed by decantation	Not more than 3

The sieves and method of making sieve analysis shall conform to the Standard Method of Test for Sieve Analyses of Aggregates for Concrete (Serial Designation: C41–24) of the American Society for Testing Materials (Appendix 3).

The decantation test shall be made in accordance with the Tentative Method of Decantation Test for Sand and Other Fine Aggregates (Serial Designation: D136–22T) of the American Society for Testing Materials (Appendix 4).

Fine aggregate shall be of such quality that mortar briquettes, cylinders, or prisms, consisting of one part by weight of portland cement and three parts by weight of fine aggregate, mixed and tested in accordance with the methods described in the Standard Specifications and Tests for Portland Cement (Appendix 1), will show a tensile or compressive strength, at ages of 7 and 28 days, not less than 100 per cent of that of 1:3 standard Ottawa sand mortar of the same plasticity made with the same cement. Concrete tests shall be made in accordance with the Standard Methods of Making Compression Tests of Concrete (Serial Designation: C39–25) of the American Society for Testing Materials (Appendix 8).

In testing an aggregate, care should be exercised to avoid the removal of any coating on the grains which may affect the strength. Sand should not be dried before being made into mortar, but should contain its natural moisture. The quantity of water contained may be determined on a separate sample, and the weight of the sand in the test corrected accordingly.

Sand, when tested in accordance with the Standard Method of Test for Organic Impurities in Sand for Concrete (Serial Designation: C40-22) of the American Society for Testing Materials (Appendix 5), shall show a color not darker than the standard color, unless it complies with the strength requirements of the preceding paragraphs.

Fine aggregate, which does not conform to the above requirements for grading, mortar strength, or color, may be used only when approved by the engineer, and then in such proportions as he may require.

The test for the unit weight of the fine aggregate shall be made in accordance with the Standard Method of Test for Unit Weight of Aggregate for Concrete (Serial Designation: C29-21) of the American Society for Testing Materials (Appendix 2), and the results included with the other test data for the fine aggregate.

Fine aggregate shall be stored so as to avoid the inclusion of foreign materials. Frozen aggregate or aggregate containing lumps of frozen material shall be thawed before using.

Exercises.—A sieve test of a sand gave the following results:

	Per Cent
Passing No. 4 sieve	100
Passing No. 50 sieve	34
Weight removed by decantation	2.7

Does this sand pass the specifications for grading and weight removed by decantation for fine aggregate for concrete?

A sieve analysis of a 500-gram sample of a sand gave the following results:

Passing No. 4 sieve	486 g.
Passing No. 8 sieve	420 g.
Passing No. 16 sieve	315 g.
Passing No. 30 sieve	170 g.
Passing No. 50 sieve	82 g.
Passing No. 100 sieve	12 g.

Plot a sieve analysis curve for this sand on a sheet of cross-section paper, plotting percentages passing as ordinates (vertically) and sieve openings as abscissae (horizontally).

Does this sand pass the specifications for the grading of a fine aggregate given in this article?

Compute the fineness modulus of this sand.

COARSE AGGREGATES

The coarse aggregates commonly used in concrete are river and bank gravels, crushed limestone, granite, trap rock, blast fur-

nace slag, and cinders. The gravels frequently contain dirt, silt, and sand, and often require washing and screening before being usable. In general, a bank-run gravel should not be used in concrete unless it has been thoroughly tested and found to be satisfactory. It is usually necessary to wash a bank-run gravel and then screen out either its fine or its coarse material. When available, a good gravel is a very economical coarse aggregate for concrete. Crushed limestone, granite, and trap rock are all good for a concrete aggregate. A good, crushed-rock concrete is frequently a little stronger than a gravel concrete of the same proportions. Rocks such as shales, most of the sandstones, and very soft limestones are unsuitable as a coarse aggregate. Cinders of good quality have been used as coarse aggregates where light weight rather than strength is desirable. Blast-furnace slag, with a low sulphur content, may make an excellent concrete aggregate, but, because of its porosity, it should not be used in thin sections which may be subjected to water action.

Visual inspection of a supply of coarse aggregate will give a good idea as to the mineral constituents, uniformity of supply, and approximate grading of the particular aggregate. The presence of dirt, clay and silt in the coarse aggregate may also be detected.

In general, any crushed stone or gravel is suitable for concrete work that is durable and strong enough, so that the strength of the concrete is not limited by the strength of the aggregate. Desirable properties are density, hardness, toughness, strength, durability, grading, and cleanliness. The best coarse aggregate for concrete work, as to grading, is one that has a comparatively large fineness modulus and a small percentage of voids. For massive concrete work, the maximum size of the particles may be 2.5 or 3 in., while in reinforced concrete work the maximum size may be 0.75, 1, or 1.50 in. The coarse aggregate must not be so large that it will not work freely around the reinforcement and into the crevices and corners of the molds and forms without extra tamping and rodding.

Of the igneous rocks, granite and trap are suitable materials for coarse aggregate. Of the sedimentary rocks, compact calcium and magnesium limestone make excellent coarse aggregates. A very soft limestone, or a limestone containing a large percentage

of clay, will probably not prove to be a good material for concrete. Most of the sandstones do not make good aggregates, because of their tendency to disintegrate. Some sandstones, in which the cementing material is lime carbonate, have been successfully used as coarse aggregates. Gravel which is clean and of a good mineral quality is a very satisfactory concrete material. Crushed rocks or gravels containing particles of clay, shale, or mica, or having thin, elongated, laminated, or friable pieces do not make good concrete aggregates.

The percentage of voids in common crushed stone and gravel varies from about 30 to 55 per cent, depending to some extent on

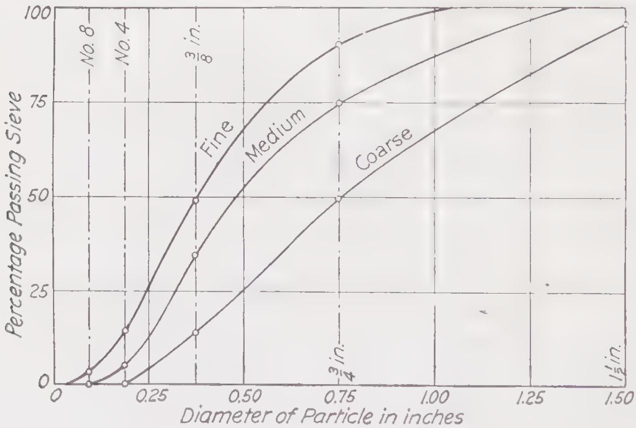


FIG. 2.—Typical mechanical analyses of fine, medium, and coarse gravels.

the shape of the particles, the grading, and the degree of compactness. The weight per cubic foot of crushed stone and gravel will vary from 75 to 120 lb., the gravel usually being a little heavier than crushed stone. The weight per cubic foot of cinders is frequently under 90 lb.

The specific gravity of stone and gravel varies somewhat. Approximate values are as follows: granite from 2.65 to 2.75; trap, 2.80 to 3; limestone, 2.60 to 2.70; sandstone, 2.30 to 2.60; ordinary gravel and sand, from 2.60 to 2.70. The percentage of absorption of crushed stone or gravel will usually be from 2 to 4 per cent.

The bulking effect of water on most crushed stones and gravels is inappreciable, and need not be considered when making measurements by volume.

A sieve analysis of coarse aggregate, made as described in Appendix 3, is an aid in determining the suitability of coarse aggregate for use in concrete mixes. If desired, the results of a sieve analysis may be plotted as a curve, as shown in Fig. 2, and the comparative grading of the particles shown. Sieve analysis curves for coarse aggregates of three different gradings are shown in this figure.

The fineness modulus is one way of measuring the grading of a coarse aggregate. The fineness modulus for a coarse aggregate may be defined as the sum of the percentages of the sample of coarse aggregate *retained on* (*coarser than*) the 1½-in., ¾-in., ⅜-in., and No. 4 sieves plus 500 (for the five smaller sieves), and the total divided by 100. A coarse aggregate that is good for concrete work will have a fineness modulus of from 6 to 8.

The following specifications for coarse aggregate are taken almost verbatim from the 1924 *Report* of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete:

Specifications for Coarse Aggregate for Concrete.—Coarse aggregate shall consist of crushed stone, gravel, or other approved inert materials with similar characteristics, or combinations thereof, having clean, hard, strong, durable, uncoated particles free from injurious amounts of soft, friable, thin, elongated, or laminated pieces, alkali, organic, or other deleterious materials.

Coarse aggregates shall range in size according to the limits given in the following table:

Size and Grading of Coarse Aggregate

Nominal maximum size of aggregate, inches	Percentages by weight passing through standard sieves with square openings						Percentage passing not more than	
	3 in.	2 in.	1½ in.	1 in.	¾ in.	½ in.	No. 4 sieve	No. 8 sieve
3	95	..	40–75	.....	.....	..	10	5
2	..	95	.....	40–75	......	..	10	5
1½	..	..	95	......	40–75	..	10	5
1	..	..	.....	95	......	..	10	5
¾	..	..	.....	......	95	..	10	5
½	..	..	.....	......	....	95	10	5

The test for size and grading of aggregate shall be made in accordance with the Standard Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C41–24) of the American Society for Testing Materials (Appendix 3).

Coarse aggregate which does not conform to the above requirements may be used only when approved by the engineer, and then in such proportions as he may require.

The test for unit weight of coarse aggregate shall be made in accordance with the Standard Method of Test for Unit Weight of Aggregate for Concrete (Serial Designation: C29–21) of the American Society for Testing Materials (Appendix 2), and the results included with the other test data for the coarse aggregate.

Coarse aggregate shall be so stored as to avoid the inclusion of foreign materials. Frozen aggregate or aggregate containing lumps of frozen material shall be thawed before using.

Exercises.—A sieve test of a bank gravel gave the following results:

	Per Cent
Passing the 1½-in. sieve	96
Passing the ¾-in. sieve	67
Passing the No. 4 sieve	12
Passing the No. 8 sieve	9

Is the grading of this bank gravel satisfactory, if the gravel is to be used for concrete work? Why?

A sieve analysis of a crushed stone gave the following results:

Sieve size and number	1.50 in.	0.75 in.	0.375 in.	No. 4
Percentage passing	100	69	18	5

Plot the sieve analysis curve for this crushed stone on a sheet of cross-section paper, plotting percentages passing as ordinates and sizes of sieve openings as abscissae.

Does this crushed stone pass the specifications for grading for coarse aggregate in this article?

Compute the fineness modulus of this crushed stone.

WATER FOR CONCRETE MIXES

The water used in concrete mixes should be clean and free from injurious amounts of oil, acid, alkali, or other deleterious substances, and should be of a quality fit for drinking purposes.

The presence of oil in water is shown by an iridescent surface film. Vegetable matter in water can sometimes be detected by observing floating particles. Chemical tests should be made to determine the presence of organic matter in all doubtful cases.

The acidity or alkalinity of a water may be determined by immersing strips of red and blue litmus paper. If the blue strip changes quickly to a red color, the water is dangerously aciditic. If the red strip changes quickly to a blue color, the water is dangerously alkaline. The water is neutral when there are no color changes. If the color change is very slow and faint, the water may be only slightly aciditic or alkaline, and the indication may be disregarded.

The functions of water in a concrete mix are threefold:

1. To combine chemically with the cement and give strength to the concrete.

2. To flux the cementing material over the surfaces of the particles of the aggregate.

3. To lubricate the mix so that the concrete may be readily placed in the forms.

Just enough water should be used to give a workable mixture. An excess of water: (1) reduces the strength of the concrete; (2) occupies space in the concrete, and later causes voids after drying out; (3) causes laitance, a whitish deposit on the surface of the concrete; (4) causes work planes or planes of separation between one day's work and the next; (5) reduces the water-tightness of the concrete; (6) causes poor surfaces next to the forms; (7) causes poor concrete floor surfaces, and tends to make the floors dusty; (8) tends to prevent the bonding of new to old concrete; and (9) increases the risk of concreting in freezing weather.

PROPERTIES OF CONCRETE

Compressive Strength.—In general, the compressive strength of concrete depends on the water-cement ratio in the mix, provided the concrete is of a workable consistency. This strength may be appreciably lessened by poor materials (cement, water, and aggregates), presence of impurities, too little mixing, poor placing, and improper curing or hardening. The unit compressive strength at 28 days is given by the formula:

$$S = \frac{14{,}000}{7^x}$$

where S = unit compressive strength at 28 days

x = water-cement ratio by volume

Due to poor materials or poor working conditions, the above formula may give a greater strength than is actually obtained on the job. When there is some doubt as to the quality of the materials, the presence of impurities, or the correctness of the

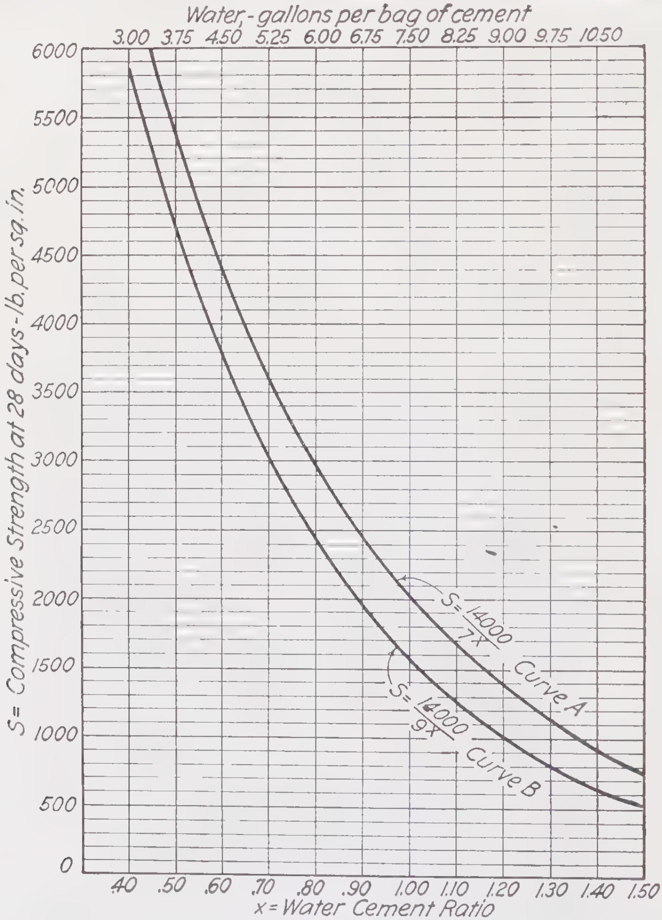


FIG. 3.—Relation between the compressive strength of concrete and the water cement ratio.

proportioning, mixing, placing, or curing, the number 7 in the formula should be replaced by 9. This strength formula then becomes:

$$S = \frac{14{,}000}{9^x}$$

The curves in Fig. 3 show the relation between the unit 28-day compressive strengths and the water-cement ratios by volume, plotted according to the above formulas.

Other formulas, which will give practically the same results for water-cement ratios varying from 0.6 to 1.6 (unit compressive strengths varying from 4500 to 600 lb. per sq. in.), are:

$$S = \frac{3700}{x} - 1700 \qquad \text{for good working conditions}$$

and

$$S = \frac{3250}{x} - 1700 \qquad \text{for poor working conditions}$$

If desired, gallons of water per sack of cement may be used instead of the water-cement ratio. Then, letting *g.s.* equal the gallons of water per sack of cement, these formulas may be written:

$$S = \frac{27{,}700}{g.s.} - 1700 \qquad \text{for good working conditions}$$

or

$$g.s. = \frac{27{,}700}{S + 1700}$$

and

$$S = \frac{24{,}000}{g.s.} - 1700 \qquad \text{for poor working conditions}$$

or

$$g.s. = \frac{24{,}400}{S + 1700}$$

For concrete mixes of equal workability, as measured by the slump test (see Appendix 7), there appears to be a relation between the amount of cement in the mix, the water-cement ratio necessary, the resultant compressive strength of the concrete, the maximum size of the aggregate, and the grading of the aggregate expressed in terms of the fineness modulus. This relation is shown graphically by the curves of Fig. 4. In general, the amount of cement and workability (slump) of the mix remaining the same, aggregates having greater fineness moduli and larger maximum sizes will require lesser amounts of mixing

water per sack of cement (lesser water-cement ratios), and thus give concretes of greater compressive strengths.

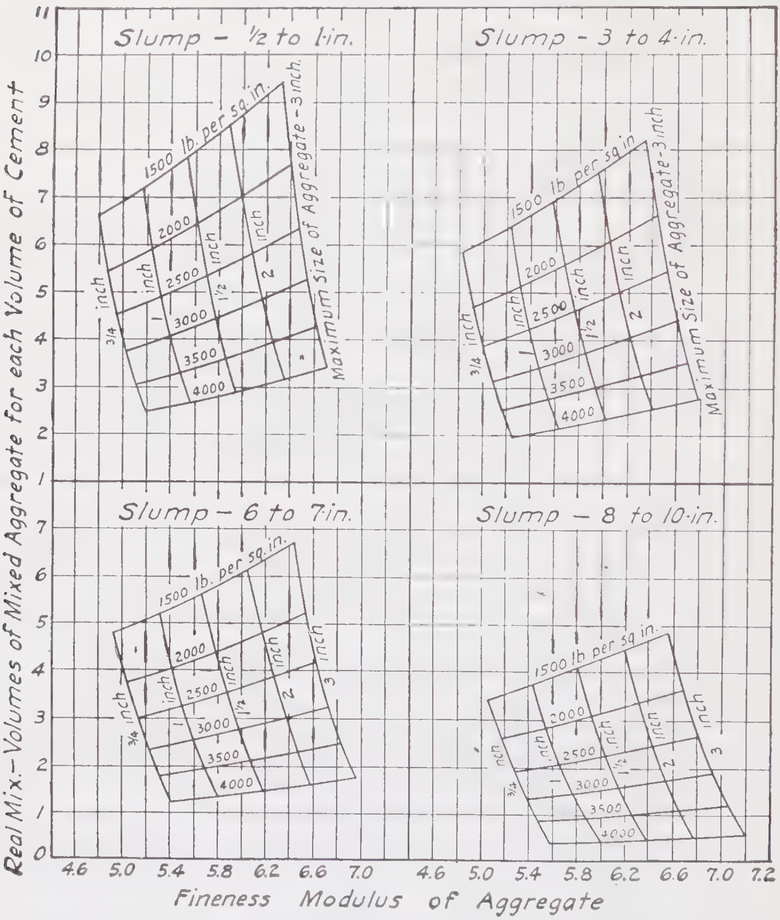


FIG. 4. –Relation of size and grading of aggregate and quantity of cement to strength of concrete. This diagram is based on the relation between strength and quantity of mixing water shown by Curve B in Fig. 3.

With good curing conditions, there seems to be a fairly definite relation between the unit 7-day and 28-day unit compressive strengths of the concrete. This relation is shown by the formula:

$$S_{28} = S_7 + 30\sqrt{S_7}$$

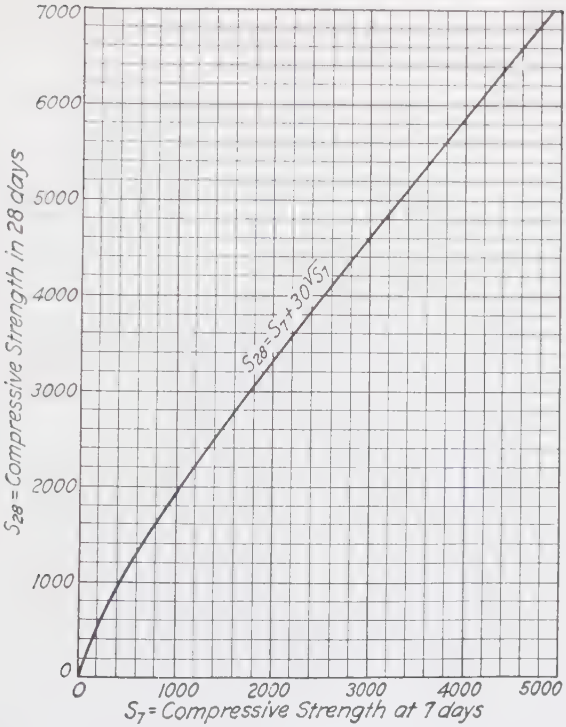


FIG. 5.—Compressive strength of concrete—seven and twenty-eight day strength relation.

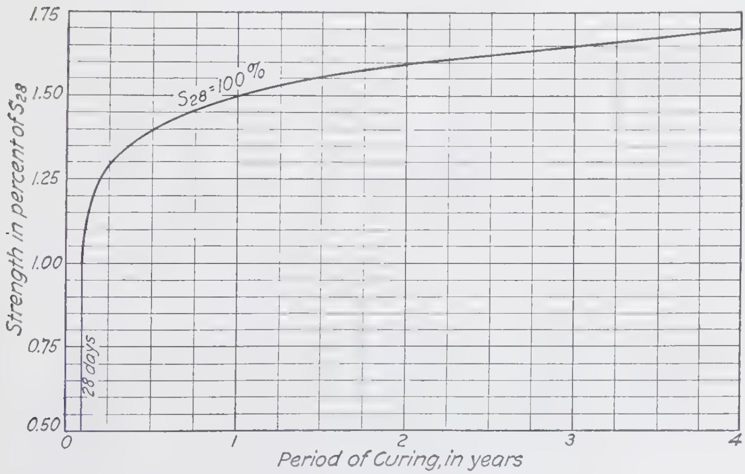


FIG. 6.—Strength-age curve for concrete.

where

$$S_{28} = \text{unit 28-day compressive strength}$$

and

$$S_7 = \text{unit 7-day compressive strength}$$

The curve in Fig. 5 shows the relation between the 7- and 28-day unit compressive strengths.

The unit compressive strength of concrete increases with age, about as shown by the curve in Fig. 6. Of course, variations in the qualities of the materials used and in the curing conditions will affect the compressive strength, and may give values which are more or less than those shown by the latter part of the curve.

Weight per Cubic Foot.—The weight per cubic foot of good sand and crushed stone or gravel concrete varies from about 135 to 160 lb. per cu. ft., with an average value of about 145 lb. per cu. ft. for plain concrete. Concrete made from cinders, slag, and other light aggregates will have a lighter unit weight than the values given.

Expansion and Contraction.—Concrete will frequently shrink a little when hardening in air, and may keep the same volume or expand a little when hardening in water. The coefficient of expansion for concrete is about 0.000006 per °F., and this coefficient varies but little for the different mixes and aggregates commonly used. The fact that a good crushed stone or gravel concrete has about the same coefficient of expansion as steel means that temperature changes will not cause the separation of the concrete and steel in reinforced concrete work.

Absorption.—The absorption of water by plain concrete may be comparatively small or great, depending on the density of the mix, richness of the mix, kind of aggregates used, and the thoroughness and care used in proportioning, mixing, placing, and curing. In general, the same factors that tend to make a concrete mix waterproof will also tend to make it non-absorptive.

Abrasion.—The abrasive resistance of plain concrete depends primarily upon the abrasive resistance of the mortar, which in turn depends upon the ability of the cement to hold the sand grains together, and upon the abrasive resistance of the sand grains themselves. When the surface of the concrete is worn away, so that the coarse aggregate is exposed, the abrasive

resistance then depends partly upon the abrasive resistance of the coarse aggregate.

Exercises.—Using both curves of Fig. 3, find the unit ultimate 28-day compressive strengths for a mix having a water-cement ratio of 0.90. For a water-cement ratio of 1.05. For a water-cement ratio of 1.20.

If the unit ultimate compressive strength of the concrete was 1770 lb. per sq. in. at an age of 7 days, what would be its probable strength at an age of 28 days?

If the unit ultimate 28-day compressive strength of concrete was 2400 lb. per sq. in., what would be its probable unit strength at 6 months? (Suggestion: Use curve showing relation of strength to age.)

How many inches would a concrete wall 80 ft. long expand, when the temperature increases from 45 to 90°F.?

EFFECTS OF VARIOUS SUBSTANCES ON CONCRETE

Tne effects of various substances on concrete may be divided into two classes: (1) the effect of various substances mixed with the concrete; and (2) the effect of various elements on the concrete.

Effect of Mixing Various Substances in Concrete. *Air.*—Air is the most common impurity present, as evidenced by air voids in the concrete. Most of the air may be removed by thoroughly compacting the concrete in the forms.

Clay and Silt.—A little finely divided clean clay or silt tends to make concrete (especially the leaner mixes) more water tight and more easy to work. An excess of clay or silt (say more than 10 per cent) may cause a decided loss of strength.

Loam and Dirt.—These materials, if organic matter is not present, have about the same effect as clay and silt. As organic matter is usually present in loam and dirt, these materials should be excluded from concrete mixes.

Organic Matter.—All organic matter should be excluded from concrete mixes, because as small an amount as $\frac{1}{10}$ of 1 per cent may be very injurious.

Lime.—Unhydrated lime (quick lime) should never be added to a concrete mix, as its expansion when hydrating will probably cause expansion and disintegration of the concrete. Thoroughly hydrated lime has about the same effect as clay, and is preferable to clay.

Mica.—A very small amount of mica mixed in concrete will cause a decided loss of strength.

Sugar.—The presence of a small percentage of sugar mixed with the concrete reduces the strength and soundness of the concrete.

Grease and Oil.—These materials have a bad effect on the qualities of concrete, when mixed with the concrete materials.

Sea Water.—It is not thought advisable to use sea water as mixing water, when making concrete, though recent tests have not shown a very great loss in strength.

Salt Water.—Waters, containing more than a few per cent of common salt in solution, may cause a decided loss in strength, and, consequently, salt should not be added to the mixing water.

Acid and Alkali Waters.—Mixing waters containing much acid or alkali frequently reduce the strength and soundness of the concrete.

Effect of Various Elements on Hardened Concrete. *Fire.*—Good concrete is little affected by fire up to a temperature of about 1200°F. (as hot as an ordinary fire). The action of fire is to cause a change in a thin layer of the outer surface of the concrete, and this layer then serves to protect the remainder of the concrete. Aggregates, which will burn or disintegratĕ under temperatures less than 1700°F., should not be used in concrete which may be subjected to fire. A fire hot enough to cause disintegration of the aggregates will, of course, cause a failure of the concrete. In some cases, the expansion and contraction, due to the application of fire and streams of water, may cause trouble. In general, concrete has better fire-resisting qualities than ordinary building stone, brick, tile, or terra cotta.

Frost.—In general, freezing has little effect on good, well-hardened concrete. Freezing and thawing of wet and comparatively porous concrete frequently cause disintegration and spalling of the exposed surfaces.

Sea Water.—Sea water appears to have little effect on good, dense, concrete, well made from materials of excellent qualities. Poor concrete, when exposed to sea water, often shows a swelling, cracking, and crumbling of the surfaces.

Alkali.—The effect of alkali water is practically the same as that of sea water.

Oils and Greases. The effect of various oils and greases is given in Appendix 10.

Acids.—In general, good, thoroughly hardened concrete is affected only by such acids as would seriously injure other materials.

Miscellaneous Liquids.—The effect of various liquids often found in different manufacturing processes is given in Appendix 10.

Exercises.—What is the general effect of the following materials on the surface of good, thoroughly hardened concrete, and what surface treatment is recommended (see Appendix 10). Heavy oils? Gasoline? Olive oil? Cider vinegar? Tanning liquors?

SECTION II

PROPORTIONING, MIXING, AND PLACING CONCRETE

JOB 1. GENERAL THEORY OF CONCRETE PROPORTIONING

Fairly recent investigations have shown that the strength of concrete depends primarily on the water-cement ratio (ratio of volume of water to volume of cement) of the mix, provided the mix is of a workable consistency. Increasing the amount of cement, or decreasing the amount of water, decreases the water-cement ratio and increases the strength, and vice versa (see Fig. 3). The least amount of water that will give a workable mix will also give the strongest concrete.

Both the economy and the workability of the mix are influenced by the grading and size of the aggregate. An increase in the fineness modulus (see page 9) and maximum size of the aggregate will usually be advantageous. For example, it has been found that, with a fixed amount of cement and water (constant water-cement ratio), the same quantity of a given aggregate will always be required to give a mix of a desired workability. The same workability may be obtained by using a greater quantity of an aggregate having a larger fineness modulus and larger maximum size. Likewise, the same workability may be obtained by using a lesser quantity of an aggregate having a smaller fineness modulus and smaller maximum size. Hence, for a mix having a definite strength (water-cement ratio) and a certain workability, the most economical aggregate to use is one having the largest permissible fineness modulus and maximum size. By largest permissible maximum size is meant that the aggregate must not be so large as to restrict a free flow of the concrete in the forms and around the reinforcement. By largest permissible fineness modulus is meant that the aggregate must not have an excess of large particles so as to make the mix harsh. The amount of the

fine aggregate in the mix should not be less than half of the amount of the coarse aggregate.

The required consistency or workability of the mix will vary for different jobs. For example, a much drier mix can be used for massive concrete work, such as large retaining walls or bridge abutments, than for a thin wall or a reinforced concrete floor.

The water-tightness of a concrete mix may be increased by the careful grading of the aggregates and the correct proportioning of the materials, so as to make the resultant mix more dense and to reduce the size and number of the voids.

Only materials of good quality should be used for concrete mixes. The portland cement should be one which has passed the standard specifications and tests. Water and aggregates of good quality should be selected as explained in Section I.

From the above statements, the following general rules for proportioning concrete may be deduced:

1. Use portland cement, water, and aggregates of good quality.
2. Base the strength on the water-cement ratio.
3. Base the required workability of the mix on the particular job, using as dry a mix as practicable.
4. Add mixed aggregate to the cement and water, to give the desired workability of mix.
5. For economy, grade and combine the fine and coarse aggregates, so that the greatest proportion of mixed aggregate can be used and yet have a mix of the desired workability.

For years, different investigators have tried to find a general rule for proportioning concrete by which its qualities and properties could be determined in advance. While no such general rule has been found and accepted by all concrete engineers, much worth-while knowledge has been obtained in regard to the proportioning of concrete mixes. This knowledge, intelligently applied, greatly reduces the amount of work required to produce a concrete mix having the desired qualities.

The effects on the qualities of the concrete mix, due to varying the water-cement ratio and the amounts and grading of the aggregates, have been fairly well determined. The effects caused by using aggregates of different types and kinds need to be more fully investigated. To quote the Bureau of Standards: "No type of aggregate such as granite, gravel, or limestone can be said

to be generally superior to all other types. There are good and poor aggregates of each type."

Consequently, the best and safest way of determining the correct proportions for a concrete mix using any one kind of aggregate is, first, to test the materials to be used, then carefully select the proportions according to the best information available, and lastly to check the qualities of the mix selected by strength and other tests.

The methods of proportioning concrete given in the following articles have been used at various times and places. Proportioning with reference to the water-cement ratio, consistency, and fineness modulus of the aggregate is the method recommended.

JOB 2. PROPORTIONING CONCRETE BY ARBITRARY PROPORTIONS

This method is the oldest and most commonly used method in this country. The materials are measured by volume, with 1 cu. ft. as the common unit of measurement. One sack of cement is taken as 1 cu. ft., and the fine and coarse aggregates are usually measured by volume in a loose condition, just as they are thrown into a wheelbarrow or measuring hopper. Enough mixing water is used to give the mix the desired consistency, which is frequently much wetter than necessary for the best results. Proportioning concrete by volume, by the method of arbitrary proportions, is proportioning by a rule-of-thumb method which is not justified either by science or good practice.

The following are some of the commonly used mixes:

1:1:2 A very rich mixture used where great strength and water-tightness are required.

1:1:3 A rich mixture not so strong as the preceding, but used for the same purposes.

1:2:4 A good mixture, used very often for reinforced concrete. Often assumed to have a compressive strength of 2000 lb. per sq. in. at an age of 28 days.

1:2:5 A medium mixture used for plain concrete floors, retaining walls, abutments, etc.

1:3:6 A lean mixture used for massive concrete under steady loads of not great intensity.

1:4:8 A very lean mixture used only for massive concrete, which supports practically no load except its own weight.

Sometimes the proportions of the mix are given as one part by volume of portland cement, to a number of parts by volume of combined fine and coarse aggregates. Some of these mixes frequently used are as follows:

1:5 About the equivalent of the 1:2:4 mix previously given.

1:6 About the equivalent of the 1:2:5 mix previously given. This 1:6 mix is often substituted for a 1:2:4 mix, but contains less cement per unit volume of concrete and has less strength than the 1:2:4 mix.

1:9 A very lean mix, equivalent to the 1:4:8 mix previously given. This 1:9 mix is often substituted for a 1:3:6 mix.

A 1:2:4 mix by volume is about the equivalent of a 1:5 mix by volume, because most of the fine aggregate in the 1:2:4 mix goes to fill the voids in the coarse aggregate, and the resulting volume of the mixed aggregate is not 6, but about 4.75. The weight per cubic foot of a combined aggregate is invariably more than that of either the fine or the coarse aggregates taken separately.

If the proportions were given by weight, then a 1:2:4 mix would be the equivalent of a 1:6 mix, because 1 lb. of cement plus 2 lb. of sand plus 4 lb. of stone is about the same as 1 lb. of cement plus 6 lb. of mixed sand and stone (exactly the same if 2 lb. of sand are mixed with 4 lb. of stone to give the combined aggregate).

Exercises.—What "standard" mix by volume is commonly used for reinforced concrete work?

What mix by volume is commonly used for basement walls?

. Show that a 1 : 9 mix by volume of cement to combined aggregate is not the same as a 1:3:6 mix by volume of cement to fine aggregate to coarse aggregate. If a numerical problem is desired, assume the weights of cement, and fine and coarse aggregates to be 100 lb. per cu. ft., and the weight of the combined aggregate to be 125 lb. per cu. ft.

JOB 3. PROPORTIONING CONCRETE WITH REFERENCE TO VOIDS

The object of this method of proportioning is to secure a concrete mix having a minimum percentage of voids, the idea being that, with other things equal, the densest mix (mix with the least

voids) will make the strongest and best concrete. It is doubtful if this method of proportioning is of much practical value unless checked by strength and other tests.

There are several variations of this method of proportioning of which the following three methods are the most common:

One variation is to use just enough mortar to fill the voids in the coarse aggregate. Due to the bulking effect, however, about 10 per cent more mortar is required. Coarse aggregates having a low percentage of voids permit a saving of cement and sand. The strength of the mix is to be increased or decreased by varying the amount of cement in the mortar.

Another variation is to mix the fine and coarse aggregates in such proportions that the resulting voids will be a minimum, and then to add the cement and water. The strength of the mix is to be governed by the amount of cement added.

A third variation (and possibly the best one) is to try several trial mixes of cement, water, and fine and coarse aggregates to find a mix that will be the most dense (have the least voids). It is assumed that this mix will be the strongest and most impervious.

JOB 4. PROPORTIONING CONCRETE BY SIEVE ANALYSES OF THE AGGREGATES AND THE MAXIMUM DENSITY CURVE

In this method of concrete proportioning, it is assumed that the densest mix can be secured by making sieve analyses of the aggregates (both fine and coarse), and then combining these aggregates and the cement with the aid of the maximum density curve. This method may be considered a variation of the void method, in which the proportions of the densest mix are secured by the help of the sieve analyses and the maximum density curve.

After the sieve analyses of the aggregates have been made, the results are plotted on cross-section paper, and a curve drawn for each aggregate. Percentages passing sieves are plotted to a vertical scale (ordinates), and diameters of sieve openings are plotted to a horizontal scale (abscissae).

Then a maximum density or "ideal" curve is drawn. This curve consists of a straight line and a portion of an elliptic curve. The straight line is drawn from the intersection of the maximum size of coarse aggregate line, with the 100 per cent line tangent to the elliptical curve. The abscissae of this point of tangency is

equal to one-tenth of the maximum size of the coarse aggregate, and the ordinate (or height of the tangent point) is equal to 35.7 per cent for crushed stone and sand, 33.4 per cent for gravel and sand, and 36.1 per cent for crushed stone and screenings.

When a fixed proportion of cement in respect to the total aggregate is used, various combinations of the fine and coarse aggre-

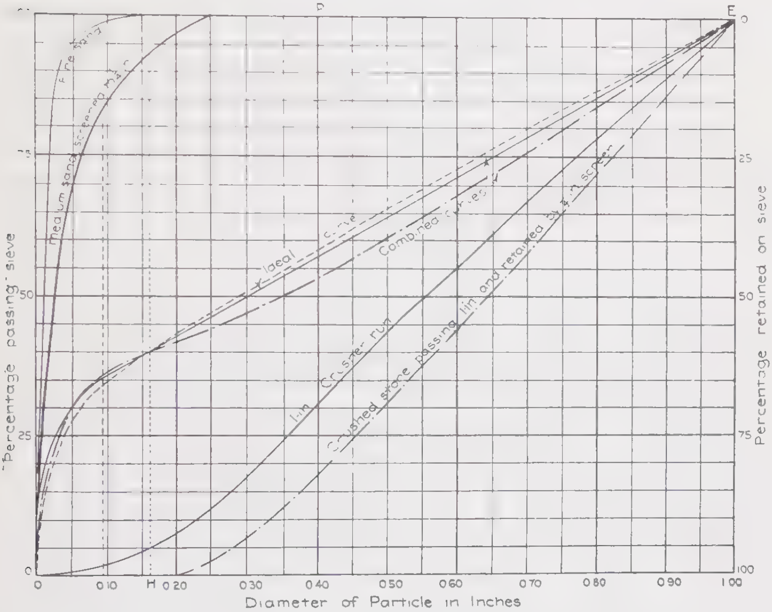


FIG. 7.—Maximum density and combined aggregate curves.

gates are tried, and the curves of the trial mixes are plotted until a mix is found, whose curve agrees fairly well with the maximum density or "ideal" curve. Sometimes it is necessary to screen the coarse aggregate into two or more sizes, in order to obtain the densest and best mixture.

For a good working concrete, the portion of the trial curve over the smaller sieve diameters should not fall below the "ideal" curve, as it is better to have a slight excess of fine material in the mix. In regard to the portion of the trial curve over the larger

sieve openings, it is immaterial whether the trial curve is a little above or a little below the "ideal" curve.

This method of proportioning is not thought to be of great practical value in designing concrete mixes for strength, because it has been found, in many instances, that trial mixes, whose curves did not closely approach the "ideal" curve, often were as strong as the trial mix whose curve agreed the closest with the "ideal" curve. For years, however, this method appeared to have been the best method found, and, when checked by strength tests, usually gave good results.

For designing impervious mixes, this method of obtaining the best proportions is very good, because the densest mix is nearly always the most water-tight mix.

JOB 5. PROPORTIONING CONCRETE BY THE SURFACE AREA METHOD

This method for finding the proportions for a concrete mix is based on the assumptions that the strength of concrete depends upon the amount of cement used in relation to the surface area of the aggregate, and upon the consistency of the mix.

The general method of procedure for proportioning concrete by this method is as follows:

1. Make sieve analyses of the aggregates.
2. Find the average number of particles per unit weight of the aggregate passing one sieve and held on another.
3. From the results of (2), and the specific gravity of the particles, compute the average volume of each size of particle.
4. Compute the surface areas from the average volumes of the various sizes and shapes of the particles. (Grains of sand and gravel are assumed as spherical, while particles of broken stone are assumed to be one-third cubes and two-thirds parallelopipeds.)
5. Determine the total surface area of the aggregates.
6. Base the quantity of cement on the total surface area.
7. Base the quantity of water on the quantity of cement and the total surface area of the aggregates.
8. Make strength tests on the mortar or concrete as determined in (7).
9. Increase or decrease the cement and water content of the mix until a mix is found that gives the required strength. The

correct water-cement ratio must always be maintained, or else the results will not be satisfactory.

The work required for this method of proportioning can be simplified in the laboratory by the use of curves and tables, showing the relations between surface areas and unit weights of particles of various shapes and sizes and specific gravities, water-cement ratios, and the relations between strength and cement content and surface areas, etc.

Results of tests do not appear to prove the correctness of the assumptions made for this method of proportioning, but tend to show that the surface area and consistency of mix are only two of several factors affecting the properties of the concrete.

JOB 6. PROPORTIONING CONCRETE BY THE USE OF THE TABLES IN THE 1924 REPORT OF THE JOINT COMMITTEE

If instructions are carefully followed, the tables given in Appendix 6 (taken from the 1924 Report of the Joint Committee) may be used to obtain the proportions of a concrete mix which will have a required compressive strength at an age of 28 days. These tables naturally cannot take into consideration all of the different types and kinds of aggregates and, consequently, there may be some aggregates for which the tabulated proportions will not give the desired strength results. Therefore, whenever time permits, control tests should be made to check the proportions selected from the tables.

When using these tables, it is assumed that good portland cement, clean mixing water, and clean and structurally sound aggregates are to be used in the concrete. The tables include possible variations in the size and grading of the aggregates, and in the consistency of the mix, as shown by the slump test.

The tables in Appendix 6 are to be used:

1. To furnish a guide in the selection of mixtures to be used in preliminary investigations of the strength of concrete from given materials.

2. To indicate proportions which *may be expected* to produce concrete of a given strength under average conditions where control tests are not made.

The method of procedure in selecting proportions from these tables is as follows:

1. Decide on the unit compressive strength to be required of the mix. (This is usually stated by the designing engineer or architect.)

2. Select the consistency of mix to be used on this particular job. (This is usually stated by the designing engineer or architect.)

3. Obtain representative samples of the fine and coarse aggregates, and determine their maximum and minimum sizes by making sieve analyses, using the sieves given in the tables. Apply the rules given on the first page of Appendix 6 when determining the size of a given aggregate to be used in connection with the tables.

4. Select the required mix from the tables, interpolating for strengths, aggregate sizes, and consistencies when necessary.

The proportions listed in the tables are by volumes of cement (based on 94 lb. equaling 1 cu. ft.) to volumes of fine and coarse aggregates compacted by rodding in the measuring box, as specified in the Standard Method of Test for Unit Weight of Aggregate for Concrete (Appendix 2).

In laboratory work, it is advisable to find the weights per cubic foot of the aggregates (as directed in Appendix 2) and then change the proportions by volume to proportions by weight.

Exercises.—Given a sand which passes a No. 4 sieve and has 16 per cent retained on a No. 8 sieve, and a crushed stone which passes a $1\frac{1}{2}$-in. sieve, has 18 per cent retained on a 1-in. sieve, has 19 per cent passing a $\frac{3}{8}$-in. sieve, and has 4 per cent passing a No. 4 sieve.

a. Select proportions for a mix to give a 28-day compressive strength of 2500 lb. per sq. in. with a consistency of mix to have a slump of 6 in.

b. Select proportions for a mix to give a 28-day compressive strength of 2750 lb. per sq. in. with a consistency of mix to have a slump of 8 in.

If the unit weights of the cement, sand, and crushed stone in the preceding question are 94, 110, and 100 lb. per cu. ft., respectively, compute the proportions by weight for the mixes selected for parts (*a*) and (*b*).

Given a sand having 3 per cent retained on a $\frac{3}{8}$-in. sieve and 22 per cent retained on a No. 4 sieve, and a gravel having 2 per cent retained on a $1\frac{1}{2}$-in. sieve, 30 per cent passing a $\frac{3}{4}$-in. sieve, and 12 per cent passing a $\frac{3}{8}$-in. sieve.

a. Select proportions for a mix to give a 28-day compressive strength of 2000 lb. per sq. in. with a slump of 8 in.

b. Select proportions for a mix to give a 28-day compressive strength of 3000 lb. per sq. in. with a slump of 4 in.

JOB 7. PROPORTIONING CONCRETE BY THE WATER-CEMENT RATIO AND SLUMP TEST

In proportioning concrete by this method, the water-cement ratio is used to determine the compressive strength of the concrete, and the slump test to determine the workability or consistency. There are three rules to be observed:

1. Use the exact amount of water with each sack of cement to produce the desired compressive strength. If there is water present in the aggregates, this water must be included when determining the amount of water used for the mix.

2. Use enough mixed aggregate with the cement and water to give a concrete mix of the consistency needed for the particular work in question. This consistency should be specified by the slump in inches.

3. If the amount of work warrants, mix the fine and coarse aggregates so that as large a proportion of mixed aggregate as is practical may be used with the cement and water, and yet have a mix of the desired consistency. In general, to avoid the possibility of a harsh mix, the weight of fine aggregate in the combined or mixed aggregate should not be more than the weight of the coarse aggregate, or less than half the weight of the coarse aggregate. In the mixed aggregate, the fine aggregate shall be that *passing* (finer than) a No. 4 sieve, and the coarse aggregate that *retained on* (coarser than) a No. 4 sieve.

For work in the field or laboratory, where the proportioning of the mix is accurately controlled, the gallons of water required per sack of cement for a desired 28-day unit compressive strength may be found from Curve A (Fig. 3), on page 18, or by the formula:

$$\text{Gallons of water per sack of cement} = \frac{27{,}700}{S + 1700}$$

where S is the 28-day unit compressive strength. Sometimes the gallons of water per sack of cement found by Curve A or the above formula are reduced by $\frac{1}{4}$ gal. per sack of cement to allow for slight errors in measuring the water.

For practical work, where it is more difficult accurately to control the proportioning of the mix, the values recommended for

use are those given by Curve B, (Fig. 3), page 18, or by the formula:

$$\text{Gallons of water per sack of cement} = \frac{24{,}400}{S + 1700}$$

These proportions of water to cement have been based on the results of a great many tests, and, consequently, may be expected to give the desired results in nearly every case. The tests, however, have not taken into consideration every kind and type of aggregate which may be used in concrete, and there may be some aggregates for which the values given in the tables will not apply. When there is any doubt, control tests should be made as a check on the compressive strength and other qualities of the mix.

For field work, 1 U. S. gal. of water may be considered as 231 cu. in., or 8.35 lb. One cu. ft. of water weighs 62.35 lb., and contains about 7.5 (7.48) U. S. gallons.

The amount of water or moisture contained in the aggregates must be found and considered when determining the number of gallons of water required per sack of cement. The aggregates should be stored and handled on the job, so that the moisture content of the aggregates will not be subject to frequent or unnecessary changes as they come to the mixer. The amount of moisture in an aggregate is rarely less than 2 per cent by weight, is usually between 3 and 4 per cent, and often is as much as 6 or 8 per cent directly after a rain. The absorption of various aggregates, expressed as a percentage of their dry weight, will average 1.0 per cent for average sand, 1.0 per cent for gravel and crushed limestone, 0.5 per cent for trap rock and granite, from 5 to 10 per cent for porous sandstone, and up to 25 per cent for very light and porous aggregate.

The amount of moisture contained in an aggregate may be found by first weighing and drying a 10- or 20-lb. sample to a constant weight, and then weighing again. The difference between the two weights gives the amount of moisture contained in the sample. The percentage of moisture should preferably be expressed in terms of the dry weight of the aggregate.

The consistency of the mix should be determined by the slump test (Appendix 7). The following maximum values of the slump in inches should not be exceeded:

Kind of concrete	Maximum slump, inches
Plain concrete:	
Mass concrete (foundations, basement walls, thick floors, etc.)	3
Comparatively thin sections (basement floors)	6
Hand-finished roads and pavements	3
Machine-finished roads and pavements	1
Mortar for floor finish	2
Reinforced concrete:	
Columns and thin, vertical sections (thin walls and partitions)	6
Heavy vertical and horizontal sections (thick walls, thick floors, and beams)	3
Thin, confined, horizontal sections	8
Thin floors and shallow beams	6

For an illustration of this method of proportioning, suppose that it is desired to find the proportions of cement, water, and mixed aggregate for a concrete mix to have a 28-day compressive strength of 2000 lb. per sq. in., and a slump of 6 in.

From Curve *A* (Fig. 3) page 18, it is seen that 7.5 gal. of water per sack of cement are needed. Deducting 0.25 gal. per sack of cement for possible errors in mixing, the amount of water to be used on the job will be $7.50 - 0.25$ or 7.25 gal. per sack of cement.

Assume that a suitable mixed aggregate (maximum size $1\frac{1}{2}$ in.), as mixed on the job, contains 2 parts of fine aggregate to 3 parts of coarse aggregate by volume, and weighs 115 lb. per cu. ft.

Also assume that under average working conditions, the average moisture content of the mixed aggregate is 3.0 per cent, and the absorption is 1.0 per cent. Then the net moisture available for use in the mix is $3.0 - 1.0$ or 2 per cent of the dry weight of the aggregate. The dry weight of the mixed aggregate will be $115 - 115 \times 0.03 = 111.5$ lb. per cu. ft.

A 1:4 mix will be tried. The amount of water in the mixed aggregate will be $4 \times 111.5 \times 0.02 = 8.92$ lb., or 1.1 gal.

Suppose that the 1:4 mix by volume with $7.25 - 1.1$ or 6.15 gal. of water per sack of cement is tested for slump, and that the slump is found to be 7 in., indicating that more aggregate can be used.

Assume, then, a 1:4.5 mix. The amount of water to be added will be $7.25 - \left(\frac{4.5 \times 111.5 \times 0.02}{8.35}\right) = 6.05$ gal. of water per sack of cement. Suppose that this mix gives a slump of $6\frac{1}{4}$ in. and is satisfactory.

The field proportions of the mix will be: 1 sack of cement to 6 gal. of water to 4.5 cu. ft. of mixed aggregates, mixed in the proportions of 2 parts of fine aggregate to 3 parts of coarse aggregate by volume. This field mix may be reasonably expected to give a concrete with a 28-day unit compressive strength of 2000 lb. per sq. in., and at the same time permit an excess of 0.25 gal. of water per sack of cement in any one batch.

Exercises.—State the three rules or principles governing the proportioning of concrete by the above method.

JOB 8. PROPORTIONING CONCRETE BY THE WATER-CEMENT RATIO, SLUMP, AND FINENESS MODULUS OF AGGREGATE

This method of concrete proportioning is based on fairly definite relations between the strength and water-cement ratio, and between the consistency (workability of the mix as measured by the slump test) and the grading of the aggregates as denoted by the fineness modulus. The compressive strength is determined by the water-cement ratio, the workability or consistency by the slump, and the economy by the grading of the aggregate as evidenced by the sieve analysis and fineness modulus.

The fineness modulus, a term used to denote the effective grading of the aggregate, is equal to one-one hundredth of the sum of the percentages of the aggregate *retained on* (coarser than) the following square mesh sieves: Nos. 100, 50, 30, 16; 8, 4, and $\frac{3}{8}$ in., $\frac{3}{4}$ in., and $1\frac{1}{2}$ in. Each sieve has a clear opening just double that of the preceding sieve. The sieve openings and the method of making the sieve analysis should conform to the specifications of Appendix 3. The coarser the aggregate, the higher the fineness modulus.

Tests have shown that mixtures of fine and coarse aggregates, having the same fineness modulus and the same amounts of cement and water, produced concretes of equal workability or consistency and of equal strength, provided the concrete mix was plastic, and that the aggregates were not too coarse for the amount of cement used. The tests also showed that, for any given mix of cement and aggregate, as the coarseness of the aggregate (fineness modulus) increased, the amount of water required for a given workability decreased. In other words, larger quantities of coarser aggregates may be mixed with a given amount of cement and water, and yet have a mix of the same workability or slump.

There is a limit, however, to the maximum fineness modulus (or coarseness of aggregate) which may be used for any given mix,

as an aggregate which contains too many coarser particles will cause the mix to be harsh and to deviate from the strength relation given by the water-cement ratio. The following table gives the approximate maximum permissible values of fineness modulus for aggregates of varying sizes and for different mixes:

MAXIMUM PRACTICAL VALUES OF FINENESS MODULUS

Size of aggregate	Volumetric ratio of cement to aggregate = real mix							
	1:1	1:2	1:3	1:4	1:5	1:6	1:7	1:9
	Maximum values of fineness modulus							
Mortars:								
0–16	3.00	2.70	2.50	2.30	2.15	2.05	1.95	1.85
0– 8	3.80	3.40	3.10	2.90	2.75	2.65	2.55	2.45
0– 4	4.75	4.20	3.90	3.60	3.45	3.30	3.20	3.05
Concretes:								
0 – 3/8	5.60	5.05	4.70	4.40	4.20	4.05	3.95	3.85
x0[1]– 1/2	6.05	5.45	5.10	4.80	4.60	4.45	4.35	4.25
0 – 3/4	6.50	5.90	5.50	5.20	5.00	4.85	4.75	4.65
x0 –1	6.90	6.30	5.90	5.60	5.40	5.25	5.15	5.00
0–1 1/2	7.35	6.70	6.30	6.00	5.80	5.65	5.55	5.40
x0 –2	7.75	7.10	6.70	6.40	6.20	6.05	5.95	5.80
0 –3	8.20	7.55	7.15	6.85	6.60	6.50	6.40	6.25

[1] *x, Half sieves not used in computing fineness modulus.*

For mixes other than those given in the table, use the values for the next leaner mix.

For maximum sizes of aggregate other than those given in the table, use the values for the next smaller size.

This table is based on the requirements of sand and gravel aggregate in ordinary uses of concrete in reinforced concrete structures. The values given in the table should be reduced by 0.25 for crushed stone, slag, or screenings, and also for concrete work of comparatively thin sections.

For concrete work, the practical limits of the fineness modulus for fine aggregates are from 2 to 4; for coarse aggregates, from 5.50 to 8; and for mixed aggregates, from 4 to 7, depending upon the maximum size of the aggregate in question and the proportions and consistency of the mix. Fig. 4, on page 20, shows the relation in graphical form.

The size of an aggregate may be determined by the following rules:

1. Use the sieves listed in Appendix 3.

2. Not less than 15 per cent of an aggregate shall be retained on the sieve next smaller than that considered as the maximum size. The minimum size of a fine aggregate is usually considered as 0.

3. Not more than 15 per cent of a coarse aggregate shall be finer than the sieve considered as the minimum size (but more than 15 per cent shall be finer than the sieve which is next larger than that considered as the minimum size).

The proportions of a real mix are by volume of cement (1 sack of 94 lb. assumed as 1 cu. ft.) to volume of dry, rodded, mixed aggregate. The proportions of a field mix are by volume of cement to volumes of aggregates as found and measured in the field. Consequently, the proportions of the two mixes may differ considerably.

When the fineness moduli for the fine and coarse aggregates are known, the proportions in which to combine these aggregates to give a mixed aggregate having a desired fineness modulus (less than that of the coarse aggregate) may be found by the formula:

$$r_f = \frac{m_c - m}{m_c - m_f}$$

where

m, m_c, and m_f are the fineness moduli of the mixed, coarse, and fine aggregates, respectively, r_f is the ratio of volume of fine aggregate to the sum of the volumes of fine and coarse aggregates measured separately.

In a 1:3:5 mix, $r_f = \dfrac{3}{3 + 5} = 0.375.$

This formula may be used to find the fineness modulus of the mixed aggregate when the proportions and fineness moduli of the fine and coarse aggregates are known. For convenience, the formula should be expressed in the following form:

$$m = r_f m_f + (1 - r_f) m_c$$

Note that $(1 - r_f)$ is the ratio of the volume of the coarse aggregate to the sum of the volumes of the fine and coarse aggregates measured separately.

When fine and coarse aggregates are mixed together in certain definite volumetric proportions, the volume of the mixed aggregate will be less than the sum of the volumes of the fine and the coarse aggregates measured separately, because a large part of the fine aggregate will tend to fill the spaces or voids in the coarse aggregate. The ratio of the volume of the mixed aggregate to the sum of the volumes of the fine and the coarse aggregates is given by the following formula:

$$r_m = \frac{r_f w_f + (1 - r_f) w_c}{w_m}$$

where w_f, w_c, and w_m are the unit weights of the dry fine, coarse, and mixed aggregates, respectively.

r_m is the ratio of the volume of dry mixed aggregate to the sum of the volumes of the dry fine and dry coarse aggregates measured separately.

r_f is the same as before.

This ratio, r_m, is sometimes called the shrinkage factor, and is used in computing the proportions of the fine and the coarse aggregates in the real mix.

The following method of procedure is suggested for finding the correct proportions, by this method, for a concrete mix to have a given compressive strength and slump.

1. Secure representative samples of the aggregates and make any preliminary tests necessary to determine their cleanliness and quality, such as tests for silt and organic impurities.

2. Determine the moisture content of the aggregates.

3. Make sieve analyses of the aggregates and determine their fineness moduli and limiting sizes.

4. Knowing the required strength and slump, determine the real mix and the fineness modulus of the mixed aggregate for this mix from the curves of Fig. 4, page 20.

5. Compute the ratios of volumes of fine and coarse aggregates to give the required fineness modulus of the mixed aggregate in the real mix.

6. Find the unit weights of the fine and coarse aggregates as they will be used in the field.

7. Find the unit weights of the dry fine and the coarse aggregates according to the method of Appendix 2.

8. Mix the dry fine and dry coarse aggregates in the proportions found in Rule 5 above, and find the unit weight of the dry mixed aggregate according to the method of Appendix 2.

9. Compute the ratio of the volume of dry mixed aggregate to the sum of the separate volumes of the dry fine and dry coarse aggregates.

10. Compute the volumetric proportions of the cement, dry fine aggregate, and the dry coarse aggregate in the real mix.

11. Determine the volumetric proportions of the field mix.

12. Determine the amount of water required per sack of cement from the proper curve of Fig. 3, page 18, and compute the net amount of water per sack of cement to be added to the field mix.

13. Mix a small batch of concrete in the required proportions for the field mix and determine the slump. If the slump found does not agree with that assumed, the mix must be reproportioned. To increase the slump a little, decrease the proportions of the aggregates slightly (say from 3 to 5 per cent), and vice versa.

14. Observe if the batch made for the slump test is too harsh or not for the work in question. If the concrete is too harsh, the mix must be reproportioned using a lesser-fineness modulus for the mixed aggregate.

15. If time permits, make and test some cylinders made from a field mix as a check on the strength.

Note that in the above procedure the strength of the concrete, and the gallons of water required per sack of cement, are based on Curve *B* of Fig. 3, page 18. If conditions in the field are such that Curve *A* of Fig. 3 may be used, the same procedure of determining the proportions of the mix applies, if the following preliminary rule is observed:

"Find the corresponding strength on Curve *B* for the same water-cement ratio, and then design the mix for this strength using the curves of Fig. 4."

For example, the required proportions of a mix, to give a compressive strength of 2500 lb. per sq. in. under Curve *A* conditions, would be the same as the proportions needed to give a strength of 2000 lb. per sq. in. under Curve *B* conditions.

Exercises.—If the size of the mixed sand and crushed stone aggregate in a concrete mix is 0:1 1/2 in., about what would be the maximum permissible value of the fineness modulus for a 1:4.4 real mix?

What is the ratio of the volume of fine aggregate to the sum of the volumes of the fine and coarse aggregates measured separately, when the fineness moduli of the mixed, fine, and coarse aggregates are 5.20, 3.10, and 6.45, respectively?

What would be the fineness modulus of a mixed aggregate containing 40 per cent of fine aggregate, if the fineness moduli of the fine and coarse aggregates are 2.95 and 6.70, respectively?

If a mixed aggregate contains 43 per cent of fine aggregate and the unit dry weights of the fine, coarse, and mixed aggregates are 107, 98, and 121 lb. per cu. ft., respectively, what would be the shrinkage factor or ratio of the volume of the dry mixed aggregate to the sum of the volumes of the dry fine and dry coarse aggregates measured separately?

If field conditions were such that the compressive strength of the concrete could be based on Curve *A* of Fig. 3, page 18, and the mix was to be designed for a compressive strength of 3000 lb. per sq. in., what strength value should be selected if the curves of Fig. 4 are to be used when designing the mix?

JOB 9. ILLUSTRATIVE EXAMPLE OF PROPORTIONING CONCRETE BY THE WATER-CEMENT RATIO, SLUMP, AND FINENESS MODULUS OF THE AGGREGATE

It was desired to proportion a concrete field mix to have a slump of about 7 in., and to give a 28-day compressive strength of 2000 lb. per sq. in. The job was comparatively large and field conditions were such that the proportioning of the aggregates could be (and were) accurately controlled, so that the use of Curve *A* of Fig. 3, page 18, was justified for determining the relation between the strength and water-cement ratio.

The method of procedure given in Job 8 was followed.

Corresponding strength of mix from Curve *B* of Fig. 3 was found to be 1550 lb. per sq. in.

1. Representative samples of the fine and coarse aggregates were secured, and the aggregates tested and found satisfactory in regard to silt and organic matter.

2. The moisture was determined and found to be 3.5 per cent for the sand, and 2 per cent for the crushed limestone by weight. The percentage of absorption was assumed as 1 per cent for both sand and crushed limestone.

3. Sieve analyses of the dry aggregates were made, and the following results obtained:

RESULTS OF SIEVE ANALYSES

Aggregate	Sieves 100	50	30	16	8	4	3/8	3/4	1½
	Percentages coarser than each sieve								
Sand	97	78	57	30	18	0	0	0	0
Stone	100	100	100	100	100	97	68	32	3

Fineness modulus of sand = 2.80, size 0 to 4.
Fineness modulus of stone = 7, size 4 to 1½.

4. From the curves of Fig. 4, page 20, a slump of 7 in., a Curve B strength of 1550 lb. per sq. in., and a maximum size of aggregate of 1½ in., gave a real mix of 1:5.5 with a fineness modulus of 5.65.

5. Ratio of volume of fine aggregate to sum of volumes of fine and coarse aggregates measured separately was found to be:

$$r_f = \frac{m_c - m}{m_c - m_f} = \frac{7 - 5.65}{7 - 2.80} = \frac{1.35}{4.20} = 0.32$$

Similar ratio for coarse aggregate = 1−0.32 = 0.68.

6. The unit weights of the aggregates as measured in the field were found to be:

Sand, damp and loose = 91.5 lb. per cu. ft.
91.5 lb. damp, loose sand = 88.3 lb. when dry
Stone damp and loose = 98 lb. per cu. ft.
98 lb. damp, loose stone = 96 lb. when dry

7. The unit weight of the dry, rodded aggregates were:

Sand = 109 lb. per cu. ft.
Stone = 103 lb. per cu. ft.

8. The unit weight of the dry rodded mixed aggregate, in the proportion of 32 per cent sand and 68 per cent stone, was 121 lb. per cu. ft.

9. Ratio of volume of dry, mixed aggregate to sum of separate volumes of dry fine and dry coarse aggregates was:

$$r_m = \frac{r_f\, w_f + (1 - r_f)\, w_c}{w_m} = \frac{0.32 \times 109 + 0.68 \times 103}{121}$$

$$= \frac{34.9 + 70.0}{121} = \frac{104.9}{121} = 0.865 \text{ (shrinkage factor)}$$

10. Volumetric proportions of cement and dry fine and dry coarse aggregates in real mix of 1:5.5 were:

$$1:\frac{5.5 \times 0.32}{0.865}:\frac{5.5 \times 0.68}{0.865} = 1:2.03:4.32$$

11. Volumetric proportions of the field mix were:

$$1:\frac{109 \times 2.03}{88.3}:\frac{103 \times 4.32}{96} = 1:2.51:4.64$$

say a 1:2.50:4.65 mix.

12. Net amount of water, per sack of cement, to be added to the mix was found as follows:

This net amount of water equals the amount required for strength (water-cement ratio) minus the amount in the aggregate plus the amount absorbed by the aggregate.

Amount required for strength = 7.5 gal. per sack of cement.

Amount contained in aggregates

= amount in sand plus amount in stone
$= 2.50 \times 88.3 \times 0.035 + 4.65 \times 96 \times 0.02$
$= 7.73 + 8.93 = 16.66$ lb.
= 2 gal. per sack of cement.

Amount absorbed by aggregates

= amount absorbed by sand plus amount absorbed by stone
$= 2.50 \times 88.3 \times 0.01 + 4.65 \times 96 \times 0.01$
$= 2.21 + 4.47 = 6.68$ lb.
= 0.80 gal. per sack of cement.

Net quantity of water to be added to mix

$= 7.50 - 2 + 8.80 = 6.30$ gal. per sack of cement.

13. A small batch of concrete in the given proportions was mixed and, when tested, gave a slump of $7\frac{1}{4}$ in., which was satisfactory.

14. The mix did not appear to be too harsh for the work in question.

15. Strength tests were made, which gave a unit compressive strength of 1085 lb. per sq. in. at an age of 7 days. The time did not permit the making of the 28-day strength tests.

The proportioning of the mix was considered as satisfactory.

Exercises.—Using the same aggregates and making similar assumptions, design a concrete mix to have a slump of from 3 to 4 in., and to give a

28-day compressive strength of 2000 lb. per sq. in. Assume that the working conditions in the field may not be very good so that Curve *B* of Fig. 3 applies.

JOB 10. CONSISTENCY OF CONCRETE

The consistency of the concrete should be such that the mix will be plastic and workable. The concrete should work readily into the corners and angles of the forms and around the reinforcement without excessive rodding, tamping, or spading. For

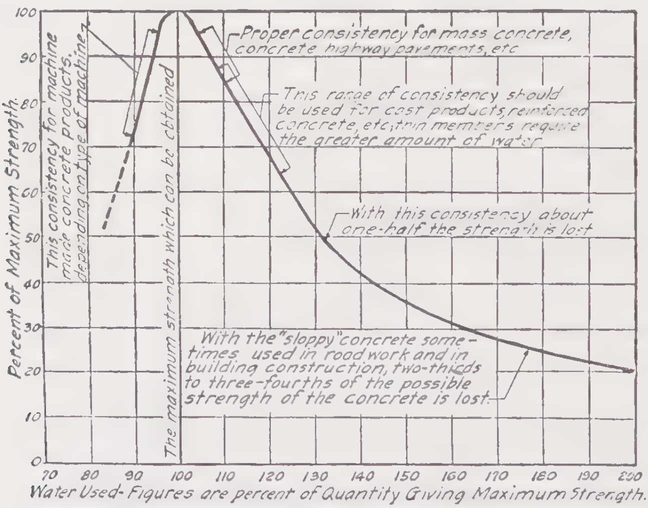


Fig. 8.—Effect of quantity of mixing water on strength of concrete. (*Abrams.*)

different kinds of work, different consistencies will be needed. A comparatively dry mix would be suitable for heavy foundations, while a much wetter mix would be needed for reinforced concrete columns and thin wall partitions. The mix should not be so wet that free water will collect on the surface.

The rule in the field should be to use as little water as possible and yet have a workable concrete mix. A comparatively slight increase in the amount of water will invariably cause a decided decrease in the compressive strength of the concrete. On some jobs where very wet mixes are used, the resulting compressive strength of the concrete may not be more than 50 per cent of

what it would have been if the amount of mixing water had been restricted to the minimum amount needed for workability.

Professor Abrams has shown conclusively the effect of varying the amount of mixing water in a concrete mix with the proportions of cement and aggregate remaining the same. The results of his investigations are shown in a graphical form in Fig. 8.

The "slump test" is recommended by the Joint Committee in their 1924 *Report* for measuring the consistency or flowability of a concrete mix (see Appendix 7). In this test, the tendency of the concrete to "slump," or reduce its height due to gravity action, is measured. The original height of the molded specimen (12 in.), minus the height (in inches) after subsidence, gives the slump in inches. An increase in the amount of mixing water will increase the slump, and vice versa. If a certain quantity of water is required for a consistency giving a slump of $\frac{1}{2}$ to 1 in., an addition of 10 per cent more water will give a slump of 3 to 4 in., 25 per cent of 6 to 7 in., and 50 per cent of about 10 in.

The following specifications for consistency are taken practically verbatim from the 1924 *Report* of the Joint Committee:

The quantity of water used shall be the minimum necessary to produce concrete of a workability required by the engineer. The consistency of the concrete shall be measured by the slump test described in the Tentative Method of Test for Consistency of Portland Cement Concrete (Serial Designation—D138-25T) of the American Society for Testing Materials (Appendix 7). The slump for the different types of concrete shall not be greater than those authorized by the table which follows, unless authorized by the engineer. The consistency shall be checked from time to time during the progress of the work.

WORKABILITY OF CONCRETE

Type of concrete	Maximum slump, inches
Mass concrete	3
Reinforced concrete:	
a. Thin, vertical sections and columns	6
b. Heavy sections	3
c. Thin, confined horizontal sections	8
Roads and pavements:	
a. Hand finished	3
b. Machine finished	1
Mortar for floor finish	2

Exercises.—Why should a wetter mix be used for thin concrete sections as reinforced concrete columns than for heavy concrete sections as massive foundations?

Briefly describe the method used in the slump test to determine the consistency of a mix of concrete.

JOB 11. MEASURING CONCRETE MATERIALS

There are two ways of measuring concrete materials in use at the present time: by volume, and by weight. The common way of measuring concrete materials by volume is to measure the cement by the sack (assuming that one sack of 94 lb. of cement equals 1 cu. ft.), and the fine and coarse aggregates loose, as they are thrown into the wheelbarrows or hopper of the mixer. Usually no correction is made for the water content of the aggregate, or the bulking effect of water in the fine aggregate. The consistency of the mix is left to the judgment of the mixer operator. Batches made by this method will usually vary greatly as to their volumetric proportions and consistency.

If the aggregates are dry and are carefully measured in measuring boxes or hoppers, the proportioning will be more satisfactory. When the fine aggregate (sand) contains some moisture, the bulking effect of this moisture in the sand must be allowed for. If allowance is not made, this bulking effect may cause an error as large as 25 or 30 per cent, when measuring the sand. A variation of 2 per cent, for example, in the moisture content, may cause a variation of about 10 per cent in the volume of the sand. It is very difficult to correct for this bulking effect, when the sand comes to the mixer with a varying moisture content.

The consistency of the mix may be controlled by slump tests made on the job. The water tank of the mixer should be so devised that the correct amount of water may be added to each batch. An automatic attachment (which can be set and locked) on the water tank of a mixer of large capacity is essential.

The best way of measuring concrete materials by volume in the field is to measure cement by the sack, the coarse aggregate loose, by the use of a measuring box or hopper, and the fine aggregate and water together, by the inundation method. It has been shown by tests that the bulking effect of water in fine aggregate is practically negligible, or very small, when the fine aggregate is

completely inundated by water. Therefore, if the volume of the fine aggregate is measured when it is covered by water, very uniform results will be obtained. After the correct amount of water has been determined for any mix, this water may be placed in a water-tight hopper and the fine aggregate then added.

Concrete materials may be measured very easily and accurately by weight by using hoppers with automatic scales. A correction must be made for the water content of the aggregates, not so much for the effect in the quantity of aggregates used as for the effect of this water content in the water-cement ratio of the batch. The water content of a batch should never vary more than $\frac{1}{4}$ gal. (about 2 lb.) per sack of cement in any particular batch.

All methods of measuring concrete materials have their advantages and disadvantages, when used on the job, and no method yet discovered is "foolproof." Probably the methods of measuring the concrete materials by weight and by volume, with the sand inundated, are the two best methods yet devised for large jobs, especially when the consistency is checked rather frequently by the slump test. The moisture contained in the aggregates is the most troublesome factor in the correct measurement of concrete materials.

Exercises.—Name some advantages and disadvantages of measuring concrete materials by:

1. Volume with cement by the sack, fine and coarse aggregates loose in barrows or hoppers, and water in a tank on the mixer.

2. Volume with cement by the sack, coarse aggregate in a measuring box or hopper, and water and fine aggregate together with fine aggregate inundated.

3. Weight with cement by the sack or pound, and with the fine and coarse aggregates and water in hoppers having automatic scales.

Given, concrete materials with the following unit weights: cement, 94 lb. per cu. ft., sand, 108 lb. per cu. ft., and crushed stone, 97 lb. per cu. ft.: (1) Find the proportions by weight of a 1:2:4 mix by volume; and (2) find the proportions by volume of a 1:2:4 mix by weight.

JOB 12. COMPUTING QUANTITIES OF MATERIALS FOR CONCRETE

The present specifications (1924 *Report* of the Joint Committee) state that the unit of measurement for concrete mixes shall be 1 cu. ft., and that 94 lb. of cement (one sack or bag or $\frac{1}{4}$ bbl.) shall be considered as 1 cu. ft.

The following approximate rule may be used in computing the quantities of materials required for 1 cu. yd. of concrete. The proportion of cement, c, is taken as unity.

Sacks of cement per cubic yard of concrete

$$= C = \frac{42}{c + s + g}$$

Cubic yards of fine aggregate per cubic yard of concrete

$$= S = \frac{1.55 \times s}{c + s + g} = \frac{C \times s}{27}$$

Cubic yards of coarse aggregate per cubic yard of concrete

$$= G = \frac{1.55 \times g}{c + s + g} = \frac{C \times g}{27}$$

When c, s, and g are the proportions by volume of cement, fine aggregate, and coarse aggregate, respectively.

If the proportions by volume are for cement and mixed (combined) aggregate, take the volume of the mixed aggregate equal to the volume of the concrete, and base the volume of cement on the volume of the mixed aggregate; that is, in a 1:6 mix by volume of cement to mixed aggregate, 1 cu. yd. of mixed aggregate and $^{27}\!/_{6}$ or 4.5 sacks of cement will be required for 1 cu. yd. of concrete. This rule will give slightly excessive quantities on large jobs, because of the bulking effect of cement and water when they are added to the mixed aggregate.

In volumetric proportioning, the amount of water is usually given as gallons of water per sack of cement. The water may be measured in a tank calibrated to read to the nearest tenth or quarter of a gallon. Sometimes the water tank is graduated to read in cubic feet. A U. S. gallon of water contains 231 cu. in., and there are approximately 7.5 gal. per cu. ft.

The computations required, when proportioning concrete materials by weight, are quite easy and simple. For example, in a 1:3:6 mix by weight, there would be 1 lb. of cement for every 3 lb. of fine aggregate and every 6 lb. of coarse aggregate. In order to change cubic feet of concrete to pounds of concrete, multiply the number of cubic feet by 145 (the approximate weight per cubic foot of good concrete).

The rule which follows may be used when computing weights of material per cubic yard of concrete (assuming a cubic yard of

concrete to weigh 4000 lb.). The proportion of cement, c', is taken as unity, and c', s', and g' are the proportions by weight of cement, fine aggregate, and coarse aggregate, respectively.

Sacks of cement per cubic yard of concrete

$$= C' = \frac{42.5}{c + s' + g'}$$

Tons of fine aggregate per cubic yard of concrete

$$= S' = \frac{2s'}{c' + s' + g'} = \frac{C' \times s'}{21.25}$$

Tons of coarse aggregate per cu. yd. of concrete

$$= G' = \frac{2g'}{c' + s' + g'} = \frac{C' \times g'}{21.25}$$

To reduce sacks of cement to pounds, multiply by 94.

The water is usually weighed when proportioning by weight, and the amount of water may be given as pounds of water per pound of cement or pounds of water per sack of cement. One U. S. gallon of water may be considered as weighing 8.35 lb.

Exercises.—Compute quantities of water (gallons), cement (sacks), sand (cubic yards), and gravel (cubic yards) for a job requiring 173 cu. yd. of concrete of a 1:1.9:3.3 mix by volume with a water-cement ratio of 1.10.

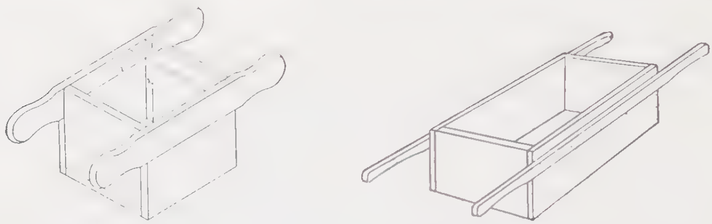
Compute quantities of water (pounds), cement (sacks), sand (tons), and stone (tons), for a job containing 124 cu. yd. of concrete of a 1:2.7:4 mix by weight with a water-cement ratio of 1.20.

JOB 13. HAND MIXING OF CONCRETE

The mixing of concrete by hand will give good results, if carefully and thoroughly done. This method of mixing is not economical except for very small jobs, where only a few batches are needed. The batches in hand mixing should be small, preferably less than 1 cu. yd., and of such size that all the concrete in any one batch can be placed in less than $\frac{1}{2}$ hr. (before initial set occurs).

The tools used in hand mixing are a water-tight metal or wooden platform, two shovels, measuring boxes for materials, and pails for measuring water. If the batch is small and only one man is available for mixing, an ordinary mortar box and a hoe can be used in place of the platform and shovels. The mixing platform should be about 7 × 12 ft. or larger in size, and should be

made of tongued and grooved plank, 2 in. thick, tightly and securely nailed on 2- × 4-in. joists spaced about 2 or 3 ft. apart. The platform should have a 2- × 2-in. strip nailed around the



(a) Measuring box of one cubic foot capacity.

(b) Measuring box of four cubic feet capacity. Inside dimensions are: length, 36 in.; width, 16 in.; and height, 12 in.

Fig. 9.—Measuring boxes. The measuring boxes have neither top nor bottom, and may easily be made of one-inch planed lumber.

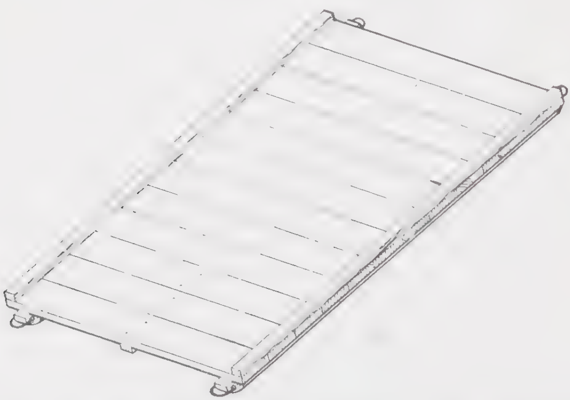


Fig. 10.—Convenient portable mixing platform. The platform should be made of 2-inch planks planed on one side, preferably of tongue-and-grooved material. The finished platform should be watertight and kept as nearly level as possible while mixing, to prevent the loss of water, which would carry off cement from the mixture. The platform should be equipped with skids or runners, so that it may be easily dragged to any desired location. A platform 12 ft. by 7 ft. will be found satisfactory for ordinary work. Concrete should never be mixed except upon a smooth, clean, watertight surface.

edges to keep the water and mortar from flowing away. The platform should be large enough to hold the batch and the two workmen who do the mixing. The depth of the measuring boxes

should be 1 or 1½ ft. rather than 6 or 8 in. The shovels should be short, flat, and square pointed. A No. 2 shovel is satisfactory.

In mixing a batch, the mixing platform is leveled in a convenient place, and the fine aggregate is measured and placed on the mixing platform in a flat pile. The cement is evenly spread over the top of the fine aggregate. This may be done by taking a

FIG. 11.—Simple tools for making and placing concrete. Water barrel and bucket; steel pan wheelbarrow for handling dry aggregate and concrete; sand screen for proper grading of aggregates; square pointed shovel for turning and mixing concrete; cast-iron concrete tamper for packing concrete; and wooden float for finishing.

sack of cement by the "ears" and letting the cement flow from the sack as the workman walks backward, by the fine aggregate. The empty cement sacks should be laid aside and counted at the end of a day's work. The used cloth sacks are bundled (tied) in groups of fifty, and sent to the cement company which gives credit for all good sacks returned. Then two workmen mix the

cement and fine aggregate by turning the mix two or three times, until the material is of a uniform color. In this work, the two workmen stand facing each other at one end of the pile. They work their shovels close to the platform diagonally towards each other, turning the shovels when they meet. There is a knack to this shovel work, which may be acquired by experience. If the batch is large, two men can start at each end of the pile and work towards the center.

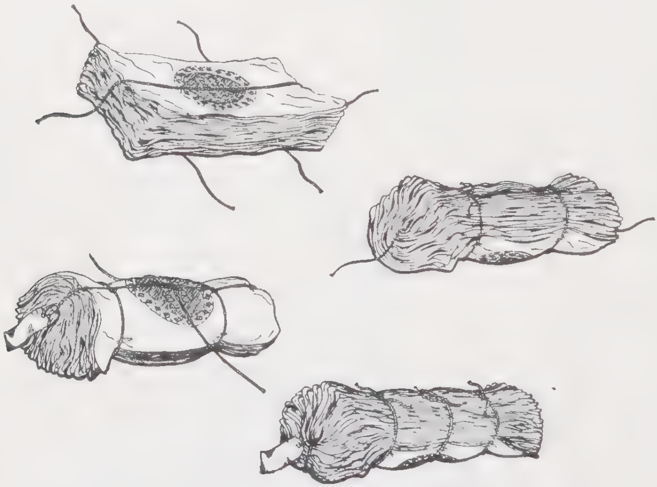


FIG. 12.—Proper method of bundling cement sacks.

Upper left: A bundle of 50 cement sacks laid out flat with two ropes 40 in. long under the pile, and with a longer rope of about 8 ft. resting on top.

Upper right: The first operation in bundling is to bring two of the ropes over the pile, as shown, tying tightly.

Lower left: After the short ropes have been tied, the bundle is turned over, and the long rope brought around and crossed in the middle of the bundle, engaging first the shorter ropes.

Lower right: Bundle of 50 cement sacks tied and tagged ready for shipment.

After the cement and fine aggregate are mixed, the mass is leveled off and the coarse aggregate measured, wetted, and spread over the pile. The batch is again turned two or three times, and then "troughed" or "ditched" in the center, and the mixing water added. This water should be carefully measured in pails, so that the same amount can be used for each batch of the same size. The dry materials are turned into the water, care being taken to prevent the escape of any water. After the materials

have been turned into the water, the whole batch is turned until it appears to have a uniform consistency. Usually about five turnings are required for thorough mixing, but most workmen stop with two or three turns. The mixing platform and tools should be washed clean at the end of the job or of the day's work.

When one man does the mixing, the dry materials can be thoroughly mixed with a hoe in a mortar box, after which the water is added and the mass thoroughly mixed again.

Correct proportioning and thorough mixing are essential to hand mixing. Excess water may mean less strength, more voids, laitance, possible washing away of the cement, and perhaps separation of the aggregates in the forms. Too little mixing means less strength, non-uniformity of consistency, and harsh-working concrete. The remixing or retempering of concrete that has partially hardened should not be permitted, even if more cement is added.

Exercises.—Why should the mixing platform be water tight?

Why should the measuring boxes be comparatively deep instead of shallow?

JOB 14. MACHINE MIXING OF CONCRETE

Machine mixing of concrete is usually much better, quicker, and more economical than hand mixing, and should be required when the amount of work is sufficient to make machine mixing economical. In several types of mixers all of the materials are placed in the mixer at once; while in some types the dry materials are mixed before the water is added. The time required for mixing depends on the type, speed, and condition of the machine, and varies for different machines. Most machines are designed to mix the materials in about 1 min.

There are two kinds of machine mixers, continuous and batch. The continuous mixer is rarely used, because the batch mixer gives easier and better control of the proportions and mixing. In a batch mixer, a batch of materials is added (or charged) to the machine, then mixed and discharged, and the cycle repeated for succeeding batches. Most of the batch mixers in use have revolving drums with fixed blades inside, though a few types have a fixed drum with moving paddles or blades. The drums may be shaped like cylinders, double cones, or cubes. The capacities of

the drums vary from about 10 to 45 cu. ft. of dry materials and from 7 to 30 cu. ft. of wet concrete. The mixing is done by moving paddles or blades, or by the rotation of the drum, the materials being raised, cut, and turned.

The mixers are usually charged by means of a lifting skip in which the dry materials are placed in the correct proportions. Some types of large mixers have overhead bins with spouts. The water is added from a tank, preferably an automatic one, usually placed over the mixer. After the batch is mixed for about 1 min., it is discharged and another batch placed in the mixer. The time of mixing should not be less than 1 min. Mixing for a longer time, even up to 30 min., will not harm the concrete. The concrete may be discharged by tilting the drum or by means of a spout. Either method is satisfactory, though the spout is preferred for large mixers.

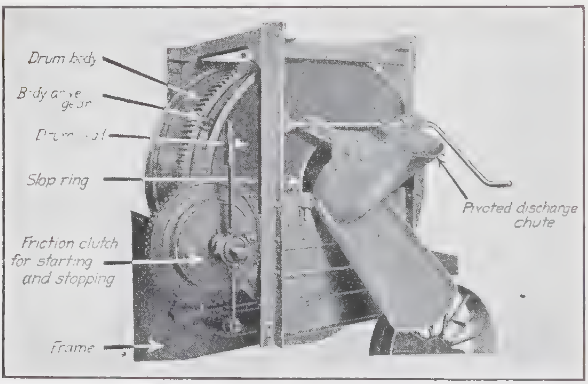


FIG. 13.—Small concrete batch mixer with parts labeled.

The speed of the drum is important. If it rotates too fast, the materials will tend to be held next to the rim, while if the speed is too slow, thorough mixing will not be accomplished in the usual time. A peripheral speed of about 200 ft. per min. is satisfactory.

At the end of the work or of each day's run, the mixer should be thoroughly washed and cleaned out. Any caked concrete adhering to the drum or blades should be broken loose and removed.

The materials used must be carefully and accurately measured, if consistent results are to be obtained. The cement may be measured by the sack. The aggregates should be measured in measuring boxes, bins, or barrows, which are comparatively deep, rather than shallow, and which allow the material to be leveled off easily. Measuring aggregates by the shovelful should not be permitted. Weighing of aggregates is usually done fairly accurately. The water may be measured in a tank, or weighed.

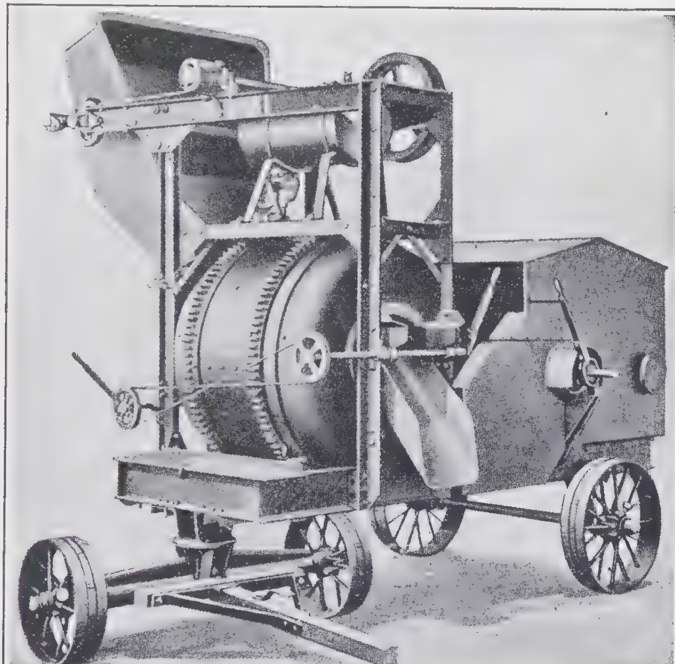


FIG. 14.—Concrete batch mixer.

The following specifications for concrete mixing are taken from the 1924 *Report* of the Joint Committee:

Specifications for Mixing of Concrete.—The mixing of concrete, unless otherwise authorized by the engineer, shall be done in a batch mixer of approved type, which will insure a uniform distribution of the materials throughout the mass, so that the mixture is uniform in color and homogeneous. The mixer shall be equipped with suitable charging hopper, water

storage, and a water-measuring device, controlled from a case which can be kept locked, and so constructed that the water can be discharged only while the mixer is being charged. It shall also be equipped with an attachment for automatically locking the discharge lever until the batch has been mixed the required time after all materials are in the mixer. The entire contents of the drum shall be discharged before recharging. The mixer shall be cleaned at frequent intervals while in use. The volume of the mixed material per batch shall not exceed the manufacturer's rated capacity of the mixer.

The mixing of each batch shall continue not less than 1 min. after all the materials are in the mixer, during which time the mixer shall rotate at a peripheral speed of about 200 ft. per min.

When hand mixing is authorized by the engineer, it shall be done on a water-tight platform. The cement and fine aggregate shall first be mixed dry, until the whole is of a uniform color. The water and coarse aggregate shall then be added, and the entire mass turned at least three times, or until a homogeneous mixture of the required consistency is obtained.

The retempering of concrete or mortar, which has partially hardened, that is, remixing with or without additional cement, aggregate, or water, will not be permitted.

Exercises.—What are the three parts or steps of the mixing cycle? Why is a batch mixer usually better than a continuous mixer?

JOB 15. CONCRETING PLANT

The fundamental principle in the design of a concreting plant is to select, arrange, and use the men, machinery, and materials so that the work will be done in the most efficient manner, especially in regard to costs.

The first thing to do is to examine the site, noting the location of the structure to be built and the space available for the concrete plant. The topography of the ground has some effect on the plant layout, in that materials preferably should not be moved uphill, and that the force of gravity may be sometimes used if the site is sloping.

The total yardage to be placed, the time limit for the job, time of year, method of delivering materials to job, available storage space, water supply, etc., all must be considered in the selection of the machinery and in the plant layout.

The size of the mixer selected depends upon the total yardage to be placed, and the time limit for this part of the work. Due allowance must be made for time required for installation and

removal, and for delays from various causes. In general, it may be assumed that the mixer will be working only about half of the working hours available.

The method used in getting the materials to the mixer is important. If the storage space is ample, comparatively large piles of coarse and fine aggregates may be placed near the mixer (the coarse aggregate should be closer, as it is larger). The cement should be stored in a weather-tight shed. If the storage space is small, it may be necessary to have the materials stored

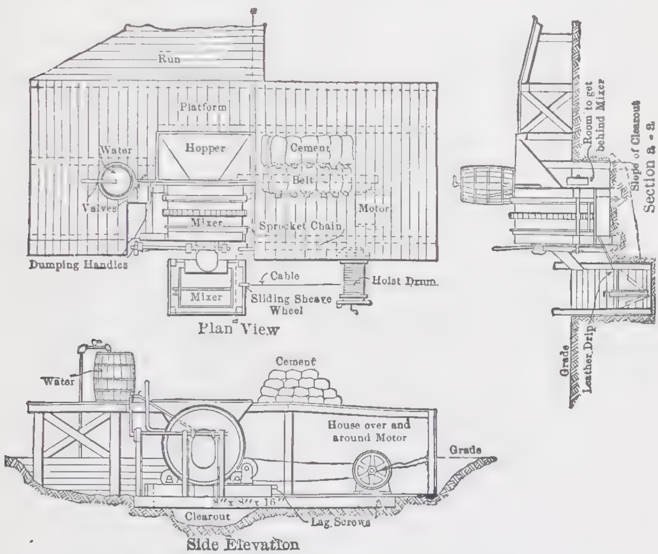


FIG. 15.—Small concrete plant layout.

elsewhere and hauled to the mixer by trucks. Care must be taken to keep dirt and other impurities out of the aggregates. If necessary, the mixing plant could be placed elsewhere, and the mixed concrete hauled to the work in trucks.

Efficient operation of the mixer is necessary for economical work. The time required for loading will vary from 10 sec. to 1 min., with an average of about 20 sec. The time of mixing should never be less than 1 min., though many mixer operators try to gain time by reducing the time of mixing. The time required for unloading requires from 10 sec. to 1 min. with an average of

30 to 35 sec. Thus the total time required for a mixing cycle varies from about $1\frac{1}{2}$ to 3 min. with an average of about 2 min. Of course, it is improbable that a batch every 2 min. could be produced hour by hour and day by day, due to delays in getting the materials to the mixer, delays in placing the mixed concrete, and delays due to breakdowns of some part of the plant.

The apparatus for measuring the materials (cement, fine and coarse aggregates, and water) for the batch must be such that the materials can be accurately and quickly measured and the correct proportions of the mix provided in all cases.

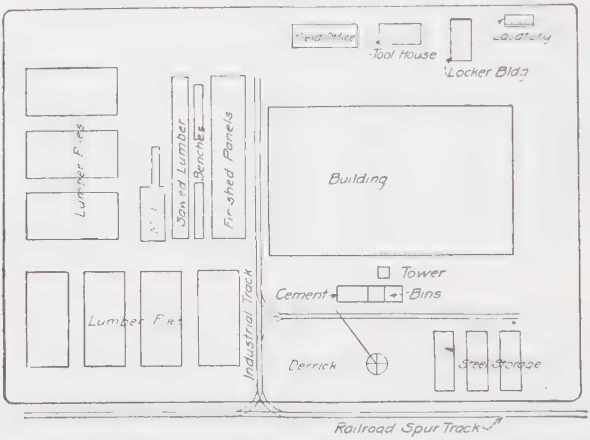


FIG. 16.—Large concrete plant layout.

The concrete coming from the mixer may be transported to the forms in one of five ways. No matter which method is chosen, it should have a capacity equal to, or a little greater than, that of the mixer, so that the operation of the mixer will not be slowed up. The methods referred to are the following:

1. By barrows or carts, in which the concrete is wheeled from the mixer to the forms. A tower and a hoist may be used for raising the carts and barrows to higher levels.

2. By a tower and spouting system, where the concrete is discharged into a skip or bucket, and this skip hoisted up a tower and dumped into a hopper, from which the concrete flows through spouts to its place in the forms.

3. By use of cableways and large buckets (either tilting or bottom dumping), to carry the concrete to the place of deposition.
4. By a bucket or spout attached to the machine (as in a large paving mixer), by which the concrete is placed in position.
5. By use of a belt conveyor to carry the concrete to the forms.

In general, no set rules may be given for the design of a concrete plant for any particular job. For some jobs one design is easily seen to be the best, while for other jobs two or three designs may be suitable. Sometimes, one large mixer is preferable to two or three small ones, and vice versa. No matter what design is selected, the plant should be well balanced as to crew, material supply, mixing capacity, and concrete transportation and deposition in forms.

When computing the total cost of a given plant on any job, the following items should be considered: (1) cost of plant; (2) cost of installation, including freight and transportation costs; (3) cost of operation; (4) cost of maintenance; (5) cost of removal: (6) depreciation; and (7) interest on investment.

The figures accompanying this job show examples of plant layouts for a small and a medium-sized job. A study of these plans will show how the general details of the plant layouts were handled.

Exercises.—State the general principle of concrete plant design. What is meant by balanced design of a concreting plant? Draw a sketch showing a plant layout for concreting a basement wall.

JOB 16. TRANSPORTATION OF CONCRETE

The transportation system must be so designed and operated that the concrete will be carried from the mixer to the forms before the initial set has occurred; that no part of the concrete will be lost in transporting; that no segregation of the materials will take place; that the delivery of the concrete be fairly continuous and uninterrupted; and that the work of transporting the concrete will be efficiently, rapidly, and economically done. The choice of a transportation system depends on the particular job and, in some instances, on the plant available.

Some of the methods of transporting concrete are shovels, chutes, wheelbarrows, carts, cars, auto trucks, buckets and cableways, belts, pipes, spouts and spouting plants (including hoists,

buckets, bins, pipes, spouts, etc.). A hoisting plant may also be used with barrows and carts.

On very small jobs, the concrete may be shoveled, chuted (in wooden chutes), or carried in wheelbarrows from the mixer to the forms.

On larger jobs (such as reinforced-concrete factory and office buildings, etc.), the use of special barrows holding about 2 cu. ft.,

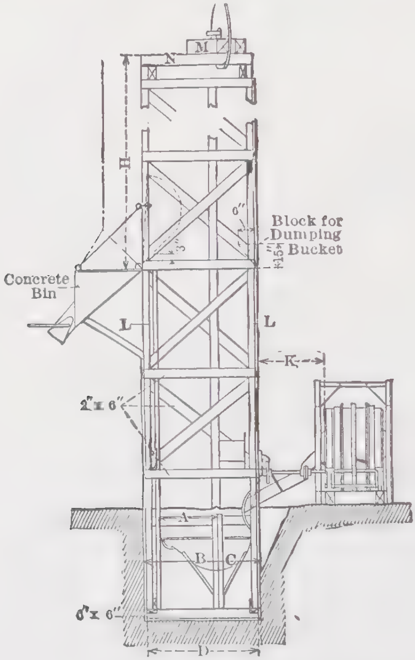


Fig. 17.—Tower for transportation plant.

or two-wheeled carts holding about 5 or 6 cu. ft., will be economical. A hoisting tower may be used to hoist the carts from the mixer level to the different floors, or the concrete may be hoisted in buckets and dumped into a bin at the floor level, the carts being loaded at the bin. Double runways must be provided for the carts so that they can pass. These runways should be of plank, and should be moved about (or taken up) as the work progresses. The hoisting towers are usually built of wood to meet the needs of the particular job. The method of transporting concrete with

carts is usually economical, and hence should always be considered when selecting the transportation system.

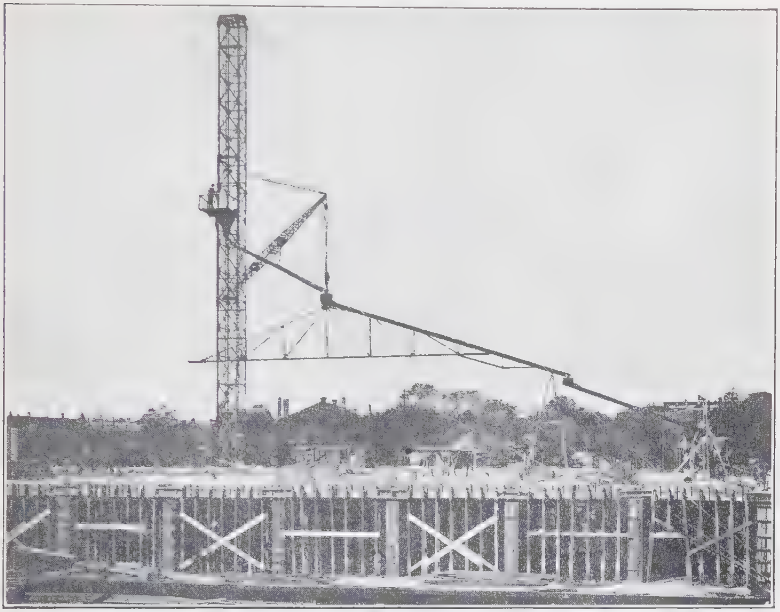


Fig. 18.—Typical boom plant installation.

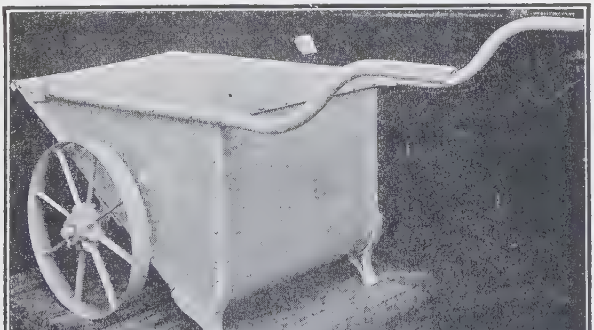


Fig. 19.—Measuring barrow.

Small dump cars running on tracks with 15- or 20-lb. rails have been used on jobs where the forms are located some distance from the mixer, as in road or tunnel work.

Large auto trucks have been successfully used to transport the concrete from a central mixing plant to the job when the available space at the site is not large enough for a complete concreting

FIG. 20.—Barrow for transporting concrete.

plant, or when it is desired to have the concrete mixed at a central plant, where the proportioning and mixing can be more scientifically controlled.

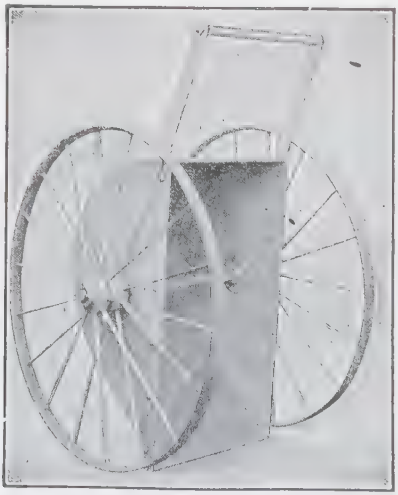


FIG. 21.—Cart for transporting concrete.

In the spouting system, the concrete is hoisted from the mixer and discharged into a small bin or hopper on the hoisting tower.

The concrete flows from this bin through metal chutes or spouts to the forms. The slope of the spouts should not be less than 1 vertical to 2 horizontal for ordinary work. The consistency of the concrete, and the slope of the spout or chute should be such that the concrete will flow evenly and uniformly, without any stoppages or segregations of materials. The spouts or chutes may be supported by suspension cables, booms, or tripods, or combinations of these three. The tripod method of support is usually limited to short distances (about 50 ft. or less), and is often used to extend the length of the cable or boom chutes. The boom system may be used up to about 200 ft., after which the

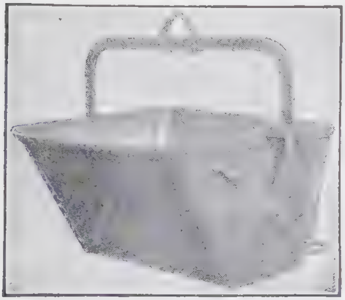


FIG. 22.—Tilting bucket.

FIG. 23.—Bottom dump bucket.

suspension cable system is better. Chutes suspended from a cable can be used for transporting concrete most any distance, by adding extra hoisting towers as they are needed. Hoisting towers are usually constructed of steel up to heights of about 200 ft.

The suspension cable and bucket system has been used on large jobs, such as dams. In this system, the bucket of concrete is carried by a suspended cableway to the forms which are to be filled. The system must include a method of raising, lowering, and dumping the buckets. Both tilting and bottom-dumping buckets have been used.

Belt conveyors have been satisfactorily used on some jobs, such as long sewers, where it is difficult to transport the concrete by other methods.

In such work as lining tunnels, a pneumatic system is essential. The concrete is forced through the pipes, by air pressure, into places and crevices where it is practically impossible to deposit it by other means.

Exercises.—Name four different methods of transporting concrete.

With the aid of sketches, describe a transportation system for concrete using a hoisting tower and carts, or a hoisting tower and spouts or chutes.

JOB 17. DEPOSITING CONCRETE IN FORMS

Careful deposition of concrete in the forms is very important as no faults in the mix or in the placing can be corrected later. Before starting to mix and pour concrete, the mixer and transporting system should be thoroughly cleaned, and all old concrete and foreign materials should be removed from the inner surfaces of the equipment. Any dirt or other debris should be removed from the forms in which the concrete is to be placed, and the surfaces of the forms thoroughly wetted (except in freezing weather) or oiled.

Concrete should be transported from the mixer as rapidly as practicable, without loss of materials or segregation. The time required for transporting and depositing should not be more than 30 min. The flow of the concrete from the mixer to the forms should be continuous, until the particular section of the forms has been filled. It is advisable to keep the surface of the concrete approximately horizontal in wall, column, or footing forms, while the junction plane in beams or slabs should be nearly vertical.

After the concrete has been deposited in the forms, it should be thoroughly compacted. The tools used are shovels, spades, forks, rods, tamping bars, etc. Spading the concrete next to the form surface tends to make a smooth surface without air pockets. The concrete must be thoroughly worked into the corners of the forms and around the reinforcement. Tamping and rodding tend to remove air voids, and increase the density and strength of the concrete unless the mix is sloppy, in which case too much tamping may tend to cause a separation of the materials. The compacting of concrete in thin forms may be helped by hammering the outside of the forms opposite the freshly deposited concrete.

Retempered or remixed concrete or mortar that has attained its initial set should not be placed in the forms.

The concrete, when deposited, should have a temperature between 40 and 120°F. In freezing weather the temperature of the concrete should not be permitted to fall below 50°F. for 72 hr., or until the concrete has thoroughly hardened.

Construction joints should be made only at the places shown on the plans. Whenever it is necessary to introduce other construction joints, the plans and design of such joints should be approved by the engineer. Construction joints in columns should be horizontal, and should be located at the under side of the floor or column capital, while the construction joints in floors and beams should be vertical and located near the center of the span.

Exercises.—Why should the forms be wetted or oiled before concrete is placed in them?

What is the object of tamping freshly placed concrete?

How much time is permitted for the transportation of the concrete from the mixer and the placing of the concrete in the forms?

In general, where should the construction joints be located?

Why should fresh concrete be kept at a temperature of 50°F. or more for 72 hr., or until it has thoroughly hardened?

JOB 18. BONDING NEW CONCRETE TO OLD

When new concrete has been deposited on or against old concrete that has set, care must be taken to secure a good bond. Perhaps the best method (and the most common one) is to chip the surface of the old concrete so as to roughen it and expose the coarse aggregate, and then thoroughly to clear away all loose material. The exposed surface should be thoroughly wetted with water, and a thick, neat cement grout added. Fresh concrete should be placed against the surface, before the grout has obtained its initial set. This method will practically always produce a good bond between the new and old concrete.

Some companies have made and placed some patented chemical compounds on the market, which are guaranteed to give a good bond between old and new concrete.

Exercises.—Why should the surface of the old concrete be chipped and cleaned?

What is the object of wetting the exposed surface?

What is the object of adding a neat cement grout?

JOB 19. PROTECTION OF CONCRETE WHEN HARDENING

After the concrete has been placed, it must be allowed to "cure" or harden. This hardening process is a rather slow chemical process, in which the cement and water unite to form compounds which give strength and durability to the concrete. In order that this hardening process may go on to the best advantage, the fresh concrete, for from about 3 days to a week, must be protected from shocks, excessive vibrations, loads, extreme heat, cold and freezing temperatures, too rapid drying out, and from contact with any impurities which may retard, stop, or destroy the chemical action.

Fresh concrete, which is almost entirely enclosed in forms (walls, for example), requires practically no protection from hot weather and dry winds. If much of the concrete surface is exposed, as in a concrete pavement, this surface should be protected from the hot rays of the sun by a covering such as a tarpaulin. After the concrete has obtained its hard set, it may be covered with dirt, sand, water, or canvas until it is a week or two old. The covering should be kept wet by sprinkling thoroughly at least once a day when necessary. If the water is evaporated from the surface before the concrete has had time to harden properly, this part of the concrete may be weakened, because not enough water will be left to combine with all of the cement.

In freezing weather, heated materials should be used and the fresh concrete kept at a temperature of 50°F. or more, until it has time to harden thoroughly (from 3 days to 1 week). This subject will be taken up in more detail later on.

Acids, alkaline solutions, and other strong liquids and oils should not be permitted to come into contact with the exposed surface of the fresh concrete until the concrete has thoroughly hardened. Many of these liquids will penetrate the fresh concrete and retard, and in some instances stop, the hardening process.

In general, the forms should not be removed until the concrete has hardened and obtained sufficient strength to carry its loads. The time required before form removal may be a week or a month, depending on the character of the concrete, weather (temperature), loading conditions, etc.

JOB 20. PLACING CONCRETE UNDER WATER

Concrete should be deposited in air whenever practicable, because the results obtained by depositing concrete under water are always more or less uncertain. When, however, the expense of depositing in air would not be warranted, concrete may be placed under water, provided several precautions are taken in the selection of the aggregates, and in the mixing, placing, and curing.

The aggregates used should be free from loam and any other material that will tend to cause laitance. Washed aggregates are preferred.

The proportions of the mix should be equivalent to a 1:4 mix by volume, or richer.

The mixing of the concrete should be very thoroughly done, and the consistency of the mix should not be too wet.

The method used in placing the concrete under water should be such as to prevent the washing of the cement out of the mix; to minimize the formation of laitance and the segregation of the materials; to avoid disturbing the concrete previously placed, before it has attained hard set; to avoid flow of water through the fresh concrete; and to avoid the formation of work planes or layers. Fairly tight cofferdams are required in flowing water to prevent the washing away of the cement. Pumping should not be permitted in the cofferdams while the concrete is being placed, and until the concrete is thoroughly hardened. The temperature of the water should not be less than 35°F. The laitance should be thoroughly removed from the surface of the concrete before resuming work after a delay or stop of any kind. The three methods commonly employed are known as: (1) the tremie method, (2) the drop bottom bucket method, and (3) the bag method.

The tremie is a long wooden box or metal tube open at the top and bottom. It must be water-tight and large enough to permit the free flow of concrete through it. The tremie may be filled by placing the lower end in a box of concrete, so as partially to seal the bottom, before being lowered in position; or by plugging the tremie with sacks which will later be forced down the tremie and out by the concrete; or by plugging the end of the tremie with sacks of concrete. The tremie must be kept full of concrete

during the time the concrete is being placed. The concrete may be discharged from the tremie by raising it a little and moving it, so that the fresh concrete moves freely and slowly out of the bottom. If a charge of concrete should be lost, the tremie must be raised and filled again.

The drop-bottom bucket is one without a top, which has bottom doors which open freely downward and outward. The bucket is filled level full with fresh concrete, and lowered slowly to avoid backwash, until it rests on the surface on which the concrete is to be placed. The bottom doors are then opened and the bucket raised very slowly until well above the concrete.

In the bag method, bags of jute or other coarse cloth are filled about two-thirds full of concrete, and placed under water by hand. The bags should be uniformly laid by "headers" and "stretchers" so as to form a compact, interlocked mass.

Exercises.—Name the three common methods used for depositing concrete under water.

Why is washed aggregate preferred for concrete work of this type?

Why should a tremie be kept full of concrete at all times during the placing of concrete?

When should comparatively rich mixes be used?

What would probably happen if water were permitted to flow through the concrete before it had hardened?

JOB 21. CONCRETING DURING FREEZING WEATHER

Satisfactory concreting may be done in cold weather, if the concrete is kept at a temperature of 50°F. or more (not over 120°F., however) from the time the materials are placed in the mixer until the fresh concrete has thoroughly hardened in the forms, a period of not less than 3 days. Successful work depends upon the following five factors:

1. The fine and coarse aggregates and mixing water should be heated to from 100 to 150°F., before being placed in the mixer. The cement may or may not be heated as it forms only a small part of the volume of the concrete.

2. The concrete should be placed in the forms (preferably warmed) immediately after mixing, so that but little of the heat will be lost. The concrete should have a temperature of not less than 70°F. when placed in the forms.

3. The concrete should be protected from the cold immediately after it is placed in the forms, so as to retain its heat.

4. The concrete in the forms must be kept at a temperature of not less than 50°F. for not less than 72 hr., and until it has thoroughly hardened.

5. The forms should not be removed too soon. It is advisable to test the concrete before removing the forms.

The best method of heating aggregates and water is by the use of steam pipes. The aggregates may be placed on top of several coils of steam pipes and covered with canvas to keep in the heat. The water may be heated by a steam coil in the water tank. An old boiler may be economically used to generate the steam required. A thermometer should be used to determine the temperature of the materials. About 1000 B.t.u. are required to heat 1 cu. yd. of materials, 1°F. Aggregates should preferably not be heated to a higher temperature than 150°F. Steam pipes are excellent for thawing frozen aggregates. Aggregates containing frozen lumps must not be used until all frozen material is completely thawed.

Another method of heating the aggregates is to use sections of an old metal smokestack or culvert. A fire is built on the inside and the aggregates are heaped over the top. Care must be taken not to heat the coarse aggregate too hot, as a stone heated to about 600°F. will retain much of its heat a comparatively long time, and may weaken the concrete by evaporating the water on its surface and leaving a thin coating of dry cement.

As soon as a batch is mixed, it should be removed from the mixer and placed in the forms as soon as possible. The temperature of the batch in the barrow or cart should be not less than 80 or 90°F., as shown by a thermometer; or the temperature of the batch, when placed in the forms, should not be less than 70°F. The forms should be cleaned of all frozen material, and should be warmed when the fresh concrete is placed in them. Forms that are enclosed in a portion of a building that is heated will usually be warm enough. Steam pipes or a stream of hot water may be used for heating the forms.

Immediately after the concrete is placed, it should be protected from the cold. Exposed concrete surfaces may be covered with panels of light sheathing, tar paper, canvas, tarpaulins, or build-

ing paper. Straw and manure are satisfactory, but manure should not come into contact with the surface of the concrete. When constructing buildings, portions of the building may be enclosed by canvas, wooden sheathing, or building paper, and the part enclosed, heated by salamanders or steam pipes, so as to keep the temperature of all parts of the enclosure above 50°F. The number of salamanders needed will vary with the outside temperature and the efficiency of the covering. The covering material should be kept at least 10 in. away from the outer forms,

Fig. 24.—Protection of building when concreting during cold weather.

so that there will be a free circulation of warm air all about the outer forms. The protection and heating should be continued from 3 to 5 days, depending on weather conditions and temperatures. Covering an exposed top of a slab with tar paper and straw immediately after pouring is a good protection against frost.

The forms should not be removed in cold weather until there is no doubt but that the concrete has thoroughly hardened. The concrete may be tested by heating the surface with a jet of hot water or steam, or with the flame of a blow torch. If the concrete is frozen, it will soften as the heat thaws the water. If the

concrete is hardened, the heat will not affect it. Frozen concrete frequently looks like hardened concrete, and will often give the same ring when struck by a hammer.

Concrete that has been once frozen before it has attained initial set can sometimes be saved by enclosing and heating it. After thawing, the concrete will set and harden if kept warm. Concrete that is frozen after setting has started is always damaged to some extent. Concrete that has been frozen, thawed, and frozen again is practically worthless in regard to strength and durability.

Common salt, calcium chloride, glycerine, alcohol, and various anti-freezing compounds have all been added to the mixing water to lower the freezing temperature of the concrete. Nearly all of these materials tend to decrease the strength of the concrete, and, consequently, should be sparingly used. Concrete hardens very slowly at temperatures below 40°F., consequently, it is far better to heat the aggregates and water, and keep the concrete at a temperature over 50°F. until it has hardened. At 40°F., concrete requires four times as long to harden as at 50°F., and nine times as long as at 70°F.

Exercises.—What are the five essentials to successful concreting in freezing weather?

How hot should the aggregates and mixing water be before being placed in the mixer?

How hot should the batch be just after it is placed in the forms?

Why should the forms be warmed?

For how long should fresh concrete be protected in freezing weather?

What should be the minimum temperature provided?

How may concrete be tested to determine if it is frozen or hardened?

JOB 22. MAKING WATERPROOF CONCRETE BY PROPER PROPORTIONING OF THE CONCRETE MATERIALS

Results of experiments show that, while it is impossible to make concrete actually waterproof, it may be made practically so by several methods. While it is difficult to keep out all of the water, yet the water may be prevented from passing through the concrete in such quantities as to cause damage and inconvenience. Concrete may be made practically water tight against heads of water up to about 40 ft.

In general, the flow of water through the concrete varies directly with: (1) the number and size of the shrinkage and

temperature cracks; (2) the amount of voids in the concrete (the voids may be comparatively large due to imperfect grading of the aggregate, excess of mixing water, segregation of materials, and improper mixing, placing, and curing); (3) the water pressure or head on the concrete; and (4) the amount of laitance. The flow of water through concrete varies inversely with the age, density, and amount of cement in the mix.

It is difficult to control the shrinkage and temperature cracks, but these cracks may be reduced in size and number by the use of well-graded aggregates, proper consistency of mix, thorough mixing, careful placing and compacting of the concrete, proper curing, and, in some instances, by the addition of temperature reinforcement. Expansion and contraction joints should be constructed very carefully.

The amount of voids in the concrete can be reduced by making the concrete more dense. This may be accomplished by using good materials, grading the aggregates, properly proportioning the cement, water, and aggregates to give the densest concrete, correct measuring of materials, thorough mixing, careful placing and compacting of the concrete in the forms, protection during curing against extremes of temperature and too rapid drying, and by using a larger proportion of cement. Proportioning the dry materials by the sieve analysis and maximum density curve method usually gives a water-tight concrete. In general, a slight excess of fine materials is desirable. A mix leaner than a 1:6 should rarely be used.

The water pressure or head on the concrete may often be reduced by providing outlets for the water at a comparatively low level, or by using drainage pipes to carry the water away.

An excessive amount of laitance (a porous, white, chalky material which often appears on the surface of fresh concrete) may be prevented by not using an excess of mixing water, by avoiding the use of dusty aggregates, by thorough mixing, by careful placing and compacting in the forms, and by avoiding "work" planes whenever possible.

JOB 23. WATERPROOFING CONCRETE BY ADDING INTEGRAL COMPOUNDS

The water-tightness of concrete may be improved by adding integral compounds in liquid form to the mixing water or in dry

form to the cement. The object of adding integral compounds is to make the concrete more dense, or water repellant, or both. In general, this method is not very efficient. A publication of the Bureau of Standards (*Technologic Paper* No. 3) states that:

> The addition of so-called "integral" waterproofing compounds will not compensate for lean mixes, nor for poor materials, nor for poor workmanship in the fabrication of concrete. Since in practice the inert integral compounds (acting simply as void-filling material) are added in such small quantities, they have very little or no effect on the permeability of concrete. If the same care be taken in making the concrete impermeable, without the addition of waterproofing materials, as is ordinarily taken when waterproofing materials are added, an impermeable concrete can be obtained.

Among the compounds added to the mixing water in a liquid or paste form are: an alum soap solution (1 part alum to 2.2. parts of soap), chloride of lime, wax, mineral oil residuum, and several specially manufactured compounds. As most of these compounds tend to weaken the strength of the concrete, large percentages should not be used.

The finely powdered, dry compounds, mixed with the dry cement, include lime, puzzolan cement, fine clay, feldspar, finely ground sand, and various manufactured substances. An addition of 10 per cent of hydrated lime, based by weight on the weight of the cement, is recommended by many engineers. Finely divided clay in an amount equal to about 5 per cent of the fine aggregate has been used in some instances. The addition of the lime or clay aids in filling the small voids in the concrete and thus making the concrete more water tight.

JOB 24. WATERPROOFING CONCRETE BY WATERPROOF COATINGS OR MEMBRANES

The surface of concrete can be made more water resistant by the addition of waterproof coatings or washes, or by layers of waterproofing material.

Among the waterproof coatings commonly applied to concrete surfaces are alum and soap mixtures (often known as "Sylvester Process"); alum, lye, and cement washes; cement grout, with or without the addition of a water repellant; paraffines, waxes, or other mineral bases applied in a melted condition, or cold in a

solution; various varnishes and paints; coatings of common oils; special bituminous (tar and asphalt) coatings; and various materials prepared by different manufacturers.

To secure good results, the concrete surface to which the coating is applied should be clean, dry, and free from foreign matter. The coating should be homogeneous, continuous, uniform, and sound. Cracks in the coating will let the water through. All of the coatings named, except the bituminous kinds, are usually applied to the concrete surface directly exposed to water action.

The Sylvester Process consists of first applying, by means of a soft brush, a boiling hot soap solution made by dissolving $\frac{3}{4}$ lb. of soap in 1 gal. of water. After the soap solution has dried (which requires about 24 hr.), the alum solution at a temperature of about 70°F. is applied with a brush. This alum solution is made by dissolving 2 oz. of alum in 1 gal. of water. The temperature of the air should not be less than 50°F., and the solutions should be well brushed in. This constitutes one treatment, and as many treatments may be given as desired.

Layers of waterproofing materials or membranes may be placed on the concrete surface on which the water pressure is applied, or else placed between two layers of concrete. The concrete surface should be hard, clean, dry, and slightly rough. The membrane must be well lapped, so as to be continuous, of as many thicknesses as required, and must be protected from injury. The several layers of the membrane are usually bound together, and to the concrete surface, by some bituminous compound.

Some of the membranes commonly used are: tarred felt, asphalt felt, special felts, burlap, burlap saturated with tar and asphalt, and combinations of canvas, felt, and burlap. The bituminous materials are: hot asphalt mastic, hot asphalt, hot coal tar, and various specially manufactured asphaltic compounds.

The membranes and bituminous materials should be applied as directed by the manufacturers. Joints in membranes should be broken at least 12 in., and laps in the membrane should be at least 12 in. Each layer of membrane and bituminous material must completely cover the surface without cracks or blow holes.

The following table is taken from "Modern Method of Waterproofing," by M. H. Lewis:

Number of Ply of Waterproofing Required for Varying Heads of Water

Head of water	Material			
	Coal tar and felt	Commercial asphalt and felt	Special felts and compounds	Asphalt mastic, thickness in inches
0	2	2	1	0.25
1	3	3	2	0.625
2	4	4	3	0.625
6	5	5	4	0.625
8	6	6	5	0.75
10	7	7	6	0.75
15	8	8	7	0.75
20	9	9	8	0.75

Exercises.—How many plys (thicknesses) of coal tar and felt would be required if the head of water is 12 ft.?

JOB 25. WOODEN FORMS FOR CONCRETE

Forms for concrete must be tight, so as to prevent leakage of mortar. They must also be properly braced and tied to keep their position and shape with no bulging and twisting, and must have strength enough to support the concrete and the construction loads which may be placed upon them.

As the cost of the form work equals from 15 to 40 per cent of the total cost of a concrete structure, it is worth while to study the design of the forms in regard to economy in labor, and in the use and re-use of the materials.

The cost of form lumber depends upon the design of the forms, re-use of the forms, replacements required at each set up, and value of form lumber at the end of the job. The labor cost of forms depends upon the cost of making units and shapes to be used, cost of erection, cost of removal (stripping), and cost of handling and erection for the next set up

The following rules should be followed in the design of lumber forms:

1. Use stock sizes and lengths of lumber, and use as few lengths as practicable.

2. Use as few units as practicable, and do not make them too heavy.

3. Allow for clearances and small inaccuracies.

4. Provide for easy stripping.

5. Provide for re-use of such units as panels, beam forms, column forms, etc.

6. Provide bevel cuts and keys, so that forms can be released without excessive prying.

The kind of lumber used for form work should be a partially seasoned spruce or pine of almost any variety that is sound and free from twists, shakes, knots, and surface decay. Hemlock is satisfactory, if it is not to be re-used, as it often weathers rapidly. The form lumber selected depends upon price, kind, and quantity available in the local market. Partially seasoned lumber is best, as green lumber may shrink and kiln-dried lumber may swell.

For all surfaces where the concrete will later be exposed, only dressed lumber should be used. Ship lap is preferable for flat work, though tongued and grooved (T and G) and dressed and matched (D and M) lumber are satisfactory. The inside surfaces of the forms should be dressed true and free from joint and other marks. Corners should be beveled when practical.

In general, the builder's knowledge and experience will enable him to select the proper sizes of lumber without special computations. The horizontal members should support the weight of the concrete and other constructions which may be placed on them, and the vertical forms should be able to resist a hydrostatic pressure of 145 lb. for each vertical foot of height. The sizes of lumber frequently used are: 2-in. stock for columns and beam and girder bottoms; 1- or $1\frac{1}{2}$-in. stock for floor panels and beam and girder sides; 1- or 2-in. stock for footings; 2- × 4-in. stock (2 × 4's) for stringers and joints; 3- × 4-in. or 4- × 4-in. stock for struts, posts, shores, and uprights; 1- or 2-in. stock for cleats; and 1- × 6-in. or $1\frac{1}{2}$- × 6-in. stock for cross ties and bracing. Dressing lumber reduces its dimensions from $\frac{1}{16}$ to $\frac{1}{8}$ in. for for each surface dressed. Common symbols for dressed lumber are S1S, S1S2E, S2S, S4S, etc., meaning, surface 1 side, surface 1 side 2 edges, surface 2 sides, surface 4 sides, etc., respectively.

The nails used in framing should be numerous and long enough to hold the forms together. Too many and too long nails require

more labor when stripping the forms and preparing the form lumber for re-use. Sizes of nails commonly used are given in the table which follows.

Sizes in pennies	Length in inches	Approximate number per pound
4	1.50	315
5	1.75	270
6	2.00	180
7	2.25	160
8	2.50	105
9	2.75	95
10	3.00	70
12	3.25	63
16	3.50	47
20	4.00	31
30	4.25	24
60	6.00	11

Whenever practical, nails need not be driven clear in to the head, as leaving the head end of the nail projecting a little makes the stripping of forms easier. A double-headed form of nail has been satisfactorily used for this purpose.

On the job, the lumber piles, sawmill (if one is used), and benches should be arranged for efficient work. Many of the units, or parts of units, such as portions of beam and column forms, panels, etc., are first prepared on the benches, and later erected in the building. Careful planning can save lumber and labor in the making, erecting, and stripping of forms.

For larger jobs, such as large reinforced concrete buildings, the drafting office should provide detailed drawings for all forms for beams, columns, slabs, etc., as well as some general assembly drawings showing how the different forms fit together. Key drawings, showing the general arrangement and layout of the work, are often required. Such elaborate drawings are not needed on small jobs, though the office man or job foreman should have rough sketches of the form work when such drawings will be helpful.

Before the concrete is poured, the interior surfaces of the forms should be thoroughly wetted with water, or oiled. Crude oil, or a mixture of kerosene and linseed oil, is commonly used. The oiling should be done before the reinforcement is placed in the forms. If the concrete walls are to be plastered later, the forms must be wetted instead of oiled, as plaster will not stick to an oiled surface.

Forms should not be removed until the concrete has set and hardened, so that it is strong enough to support the loads. The time that the forms should be left in place depends upon the temperature and humidity of the air, the loads to be carried by the concrete, and, to some extent, on the type of structural member. The following table shows good practice:

TIME REQUIRED BEFORE REMOVING FORMS

Member	Temperature		
	Above 60°F.	45 to 60°F.	Less than 45°F.
	Required time in days		
Compression members such as columns and walls	4 to 6	Not less than 10	Not until tests have been made that show that the concrete has thoroughly hardened
Side forms of beams and girders	5 to 7	Not less than 10	
Bottom forms of slabs of short span	6 to 10	Not less than 14	
Bottom forms of beams and girders	7 to 14	Not less than 14	

It is customary to leave some shores in place under the bottoms of beams, girders, and slabs, for a week or two after the side and bottom forms have been removed.

When the forms are removed, the units to be re-used should be cleaned, repaired, and piled. The rough lumber should have old nails removed, surfaces cleaned, and be sorted and piled for future use.

In general, the successful removal of the forms requires care, skill, and experience upon the part of the foreman.

Exercises.—What kinds of lumber should be used for forms?

What size of nails should be used for nailing 1-in. stock on 2- × 4-in. joists? For nailing 2-in. planks on joists?

What sizes of stock are used for forms for floor panels? Joists? Wall forms?

With an average temperature of 65°F., how long should wall forms remain in place? Beam forms?

What is the object of using double-headed nails?

JOB 26. TYPES OF WOODEN FORMS FOR CONCRETE

In this job, brief descriptions of the more general types of forms will be given. Forms for special work will be described in later jobs.

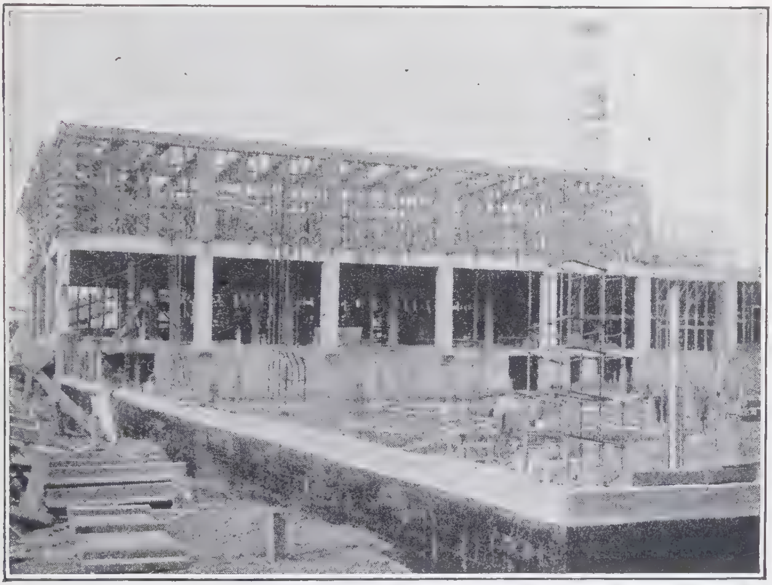


Fig. 25.—Forms for a reinforced concrete building story.

There are two types of wall forms, continuous and panel. Continuous forms are commonly used for basements walls. Such wall forms usually consist of 1-in. sheathing, nailed to 2- × 4-in. studs, and held in place by horizontal and diagonal framing. When the outside earth is hard and firm, it may be used as a part of the forms. Wire ties and wooden spreaders are frequently used in wall forms of this type.

Panel or sectional forms are economical for high walls, or on jobs where the panels can be re-used. In forms of this type the

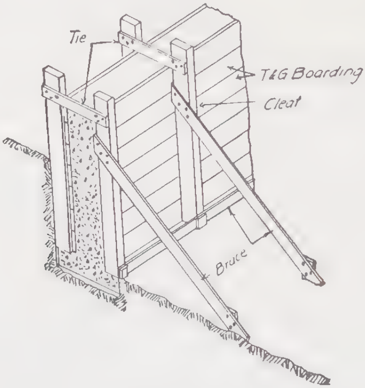


Fig. 26.—Basement wall form.

sheathing is nailed to vertical studs to form a panel and the panels are held in place by horizontal wales or rangers. Either

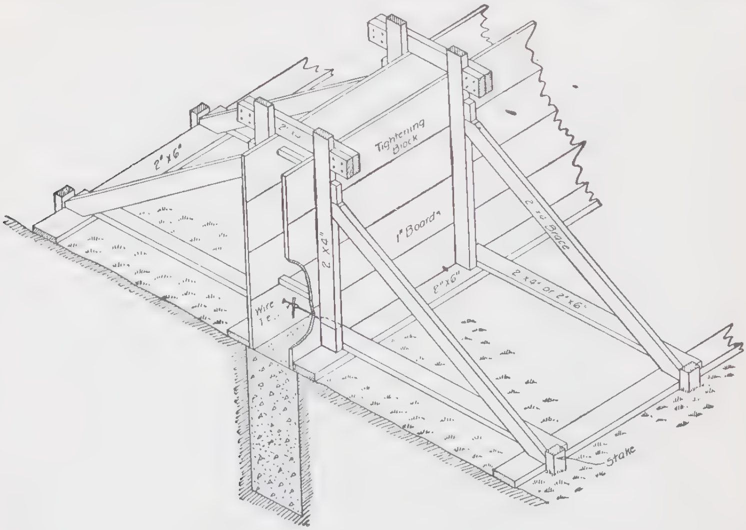


Fig. 27.—Self supporting wall form.

the studs or wales are double timbers spaced to permit the passage of the tie bolts between them. The wall panels may be

bolted or tied together with wire. Spreaders of wood or iron pipe are used to keep the forms the correct distance apart. These

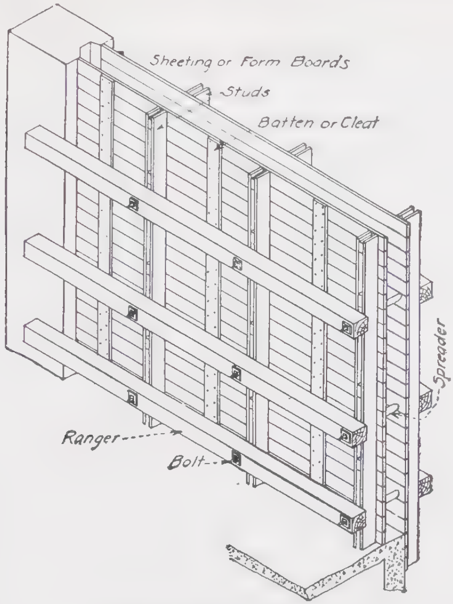


FIG. 28. -Panel wall form.

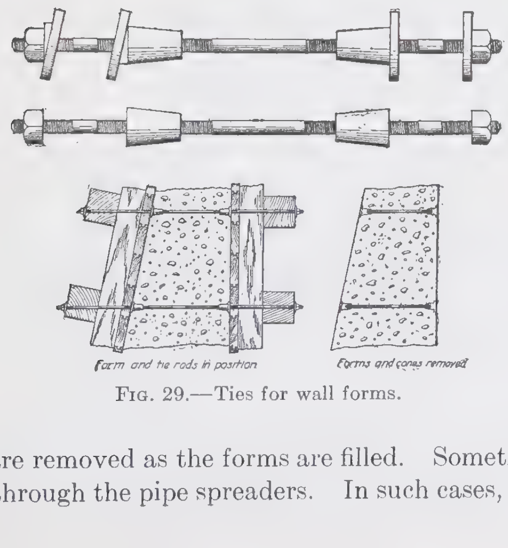


FIG. 29.—Ties for wall forms.

spreaders are removed as the forms are filled. Sometimes the tie bolts pass through the pipe spreaders. In such cases, the spread-

ers are left in the wall. Wooden washers should be placed at the ends of the pipe, so that the iron will not be exposed and later

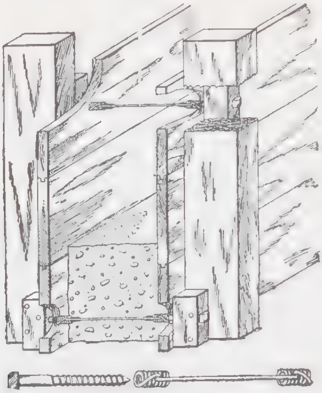


Fig. 30.—Ties for wall forms.

discolor the wall surface. When the concrete has hardened, the tie bolts (passing through the spreaders and washers) are easily

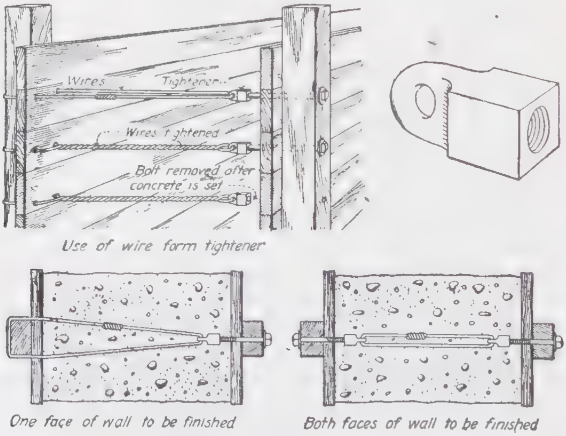


Fig. 31.—Ties for wall forms.

removed, the wooden washers cut out, and the holes filled with cement mortar.

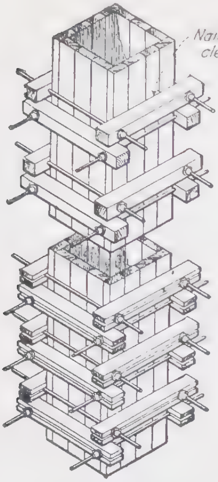


FIG. 32.—Column form.

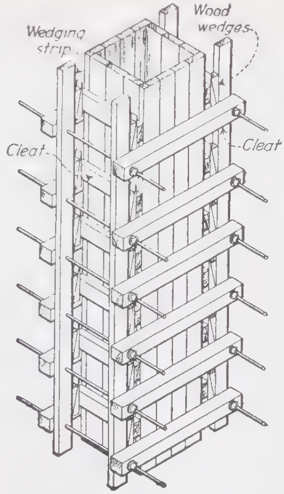


FIG. 33.—Column form.

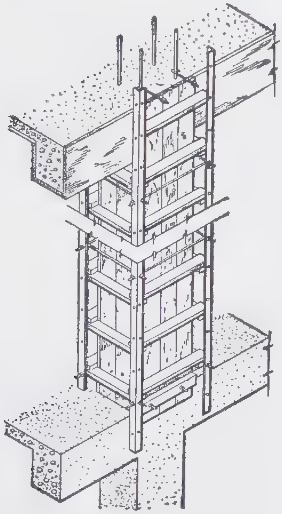


FIG. 34.—New England column clamp.

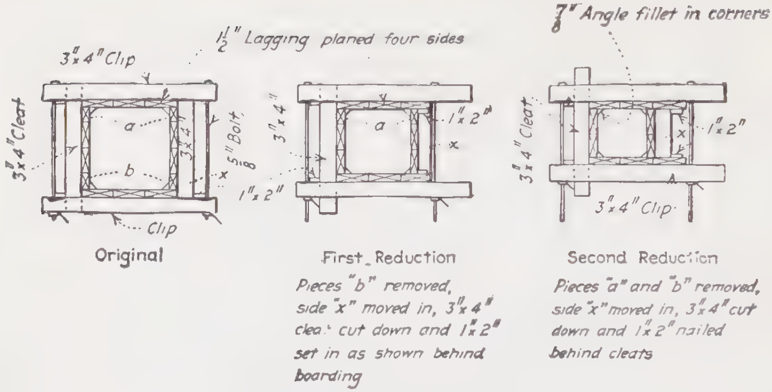


Fig. 35.—Method of reducing size of column forms.

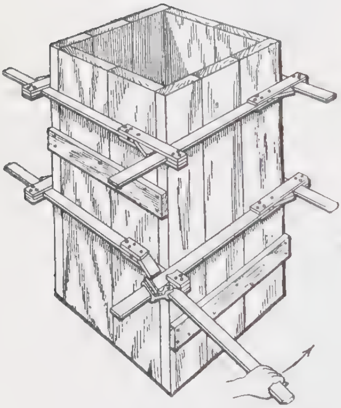


Fig. 36.—Gemco square column clamp.

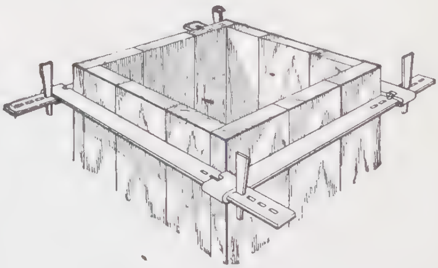


Fig. 37.—K. & W. square column clamp.

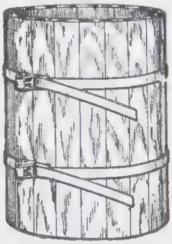


Fig. 38.—Gemco round column clamp.

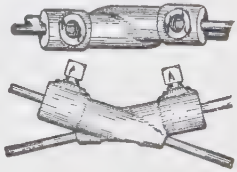


Fig. 39.—Universal round column clamp.

There are several varieties of patented wall ties on the market, most of which are devised so that parts or all of them may be

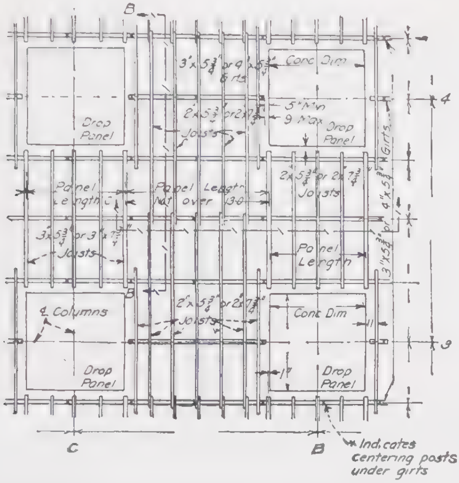


FIG. 40.—Flat slab floor forms for interior floor bay. Top view.

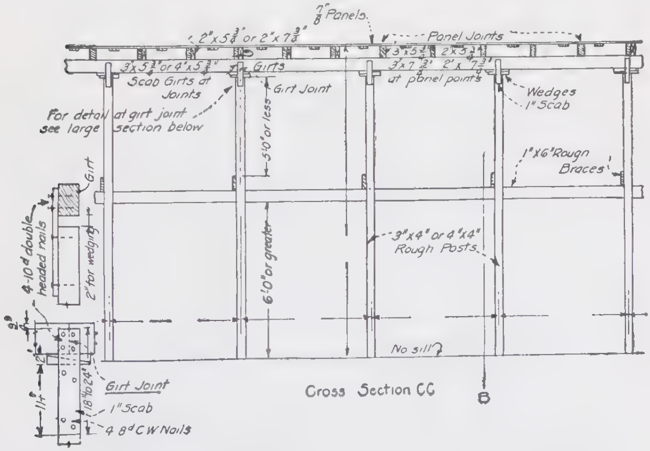


FIG. 41.—Flat slab floor forms for interior floor bay. Side view.

removed after the concrete has hardened. If iron ties are exposed in the wall surface, these ties may later cause a discoloration of the wall surface.

Concrete building columns are usually square, rectangular, round, or octagonal in shape. Round columns usually have

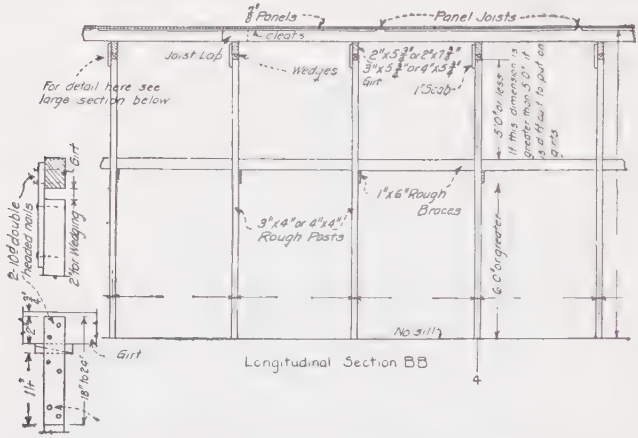


FIG. 42. -Flat slab floor forms for interior floor bay. Side view.

metal forms, while the forms for the others may be made of wood. Wooden column forms are usually made up of sections held

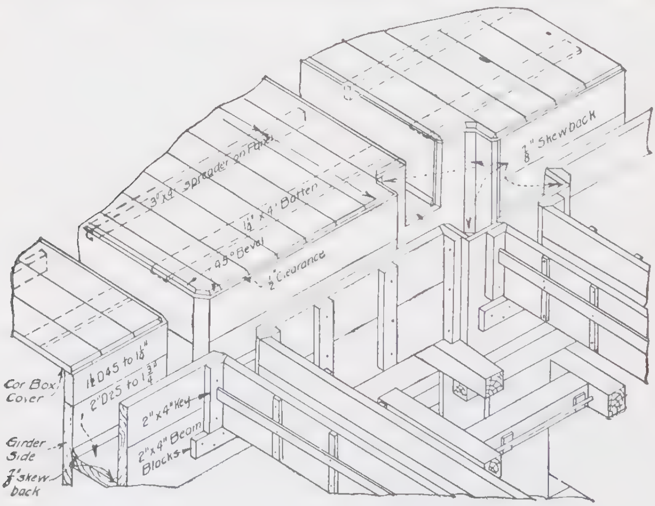


FIG. 43.—Forms for beam and girder floor system.

together by yokes, which also act as cleats. Each section is commonly used as a unit and forms one side of the column.

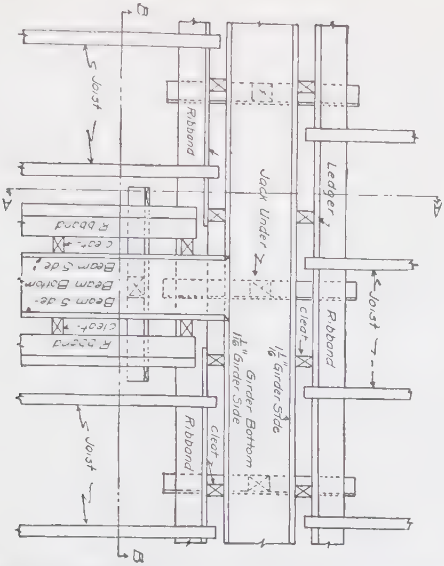


FIG. 44.—Plan of beam and girder floor formwork.

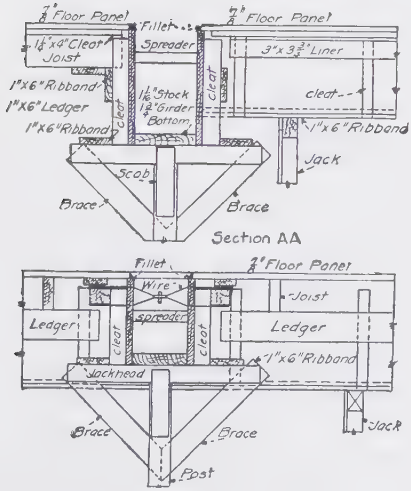


FIG. 45.—Details of beam and girder floor formwork.

A small opening is left at the bottom of each column form for the removal of sawdust, shavings, dirt, etc., just before the concrete is poured. There are various types of yokes and clamps on the market for holding the section of a column form together.

Ordinary floor forms for reinforced concrete buildings are of three types: flat slab, beam and girder, and slab. The flat-slab forms are very easy to construct unless there are drops around the column heads. These forms consist of sheathing supported by joists and stringers, which are in turn supported by posts or shores.

The forms for beam and girder floors are more complicated in their arrangement and construction, and waste more lumber. Girder sides are usually continuous and have the beams framed into them. The beam and girder sides, beam and girder bottoms,

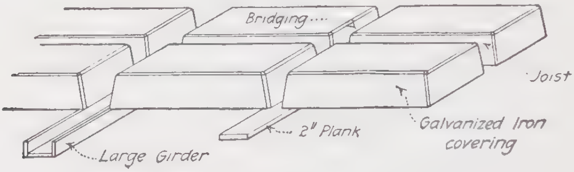


FIG. 46.—University of Wisconsin slab forms.

and slab panels, are made up separately, and erected after the column forms are in place.

The slab type of floor consists of panels in which the slab acts as both beam and slab, and which is supported by girders carried by columns. The forms for this type of floor are often of wood with a metal covering. These wooden boxes are supported by planks and shores. This type of floor form is economical when the building is rectangular in shape and the columns are uniformly spaced.

Exercises.—Name the two types of wall forms. What is the difference between them?

What are ties and spreaders? What are shores? What are column yokes?

Name the three kinds of floor forms for reinforced concrete buildings. What are the essential differences between these types of floor forms? (Use sketches.)

JOB 27. METAL FORMS

Metal forms have been used for sewers, tunnels, tanks, and retaining walls, and are now coming into use for walls, columns, beams, and slabs, due partly to the increasing scarcity and cost of suitable form lumber.

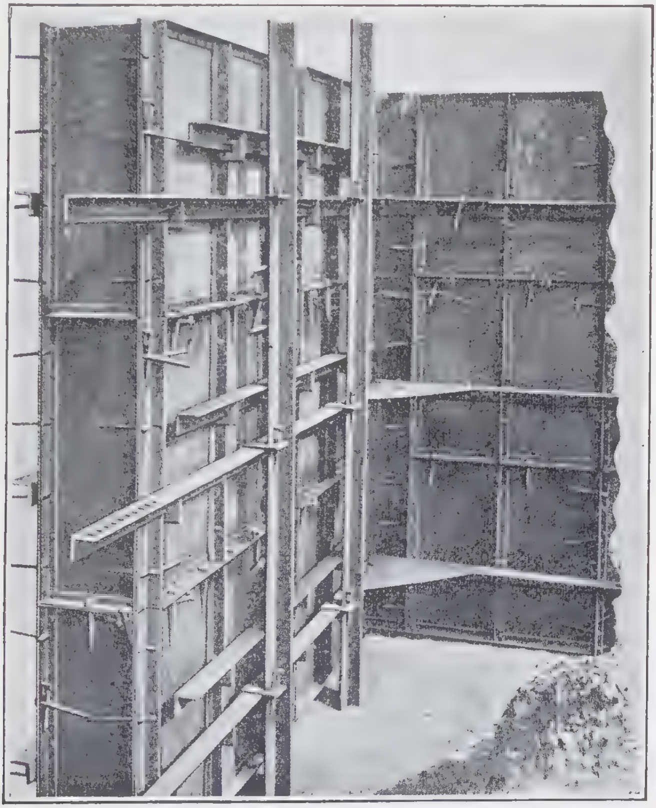


Fig. 47.—Blaw Knox Co. steel wall forms.

Wall forms are generally made in panels, and are held together by the wires, or some special form of clamp. Three common types of steel wall forms are the Blaw (Blaw Knox Co.), Hydraulic Steelcraft (Hydraulic Steelcraft Co.), and the Metaforms (Metal Forms Corp.).

The Blaw forms consist of metal standard panels reinforced on four sides with small angles. Special panels are provided to allow for various sizes and shapes of walls. The panels are fastened together by horizontal and vertical liners held in place by small wedges in slots.

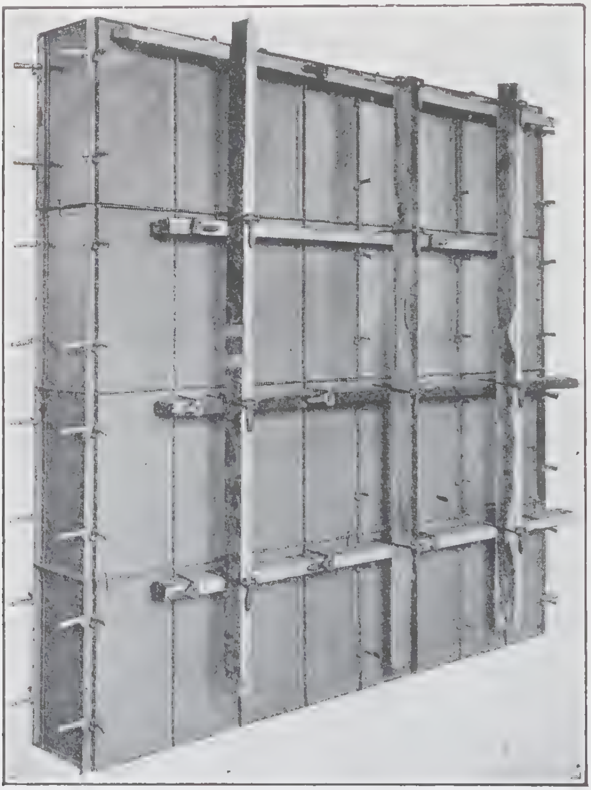


FIG. 48.—Metaforms steel wall forms.

The Hydraulic Steelcraft forms consist of light, pressed steel, U-shaped vertical liners and horizontal ribs, supporting form plates backed with wood. The framework of ribs and liners is erected first, the reinforcing steel is placed, and then the plates are fastened to the ribs and liners. Floor and roof slabs are constructed of the same equipment.

Metaforms consist of 2-ft. square sheets of annealed metal, reinforced on all four sides and in the middle with a 1 × 1-in. angle. The sheets are held together by clamps fastened to the side angles. These forms may be held apart by metal spreaders

FIG. 49.—Blaw Knox Co. steel circular column forms.

and tied by wire. Horizontal ribs and vertical liners are used to keep the units more rigidly in position.

Practically all forms for round columns with flaring heads are made of metal, and several metal forms are on the market for square, rectangular, and octagonal columns. Adjustment in the height of the forms is obtained by telescoping the lower

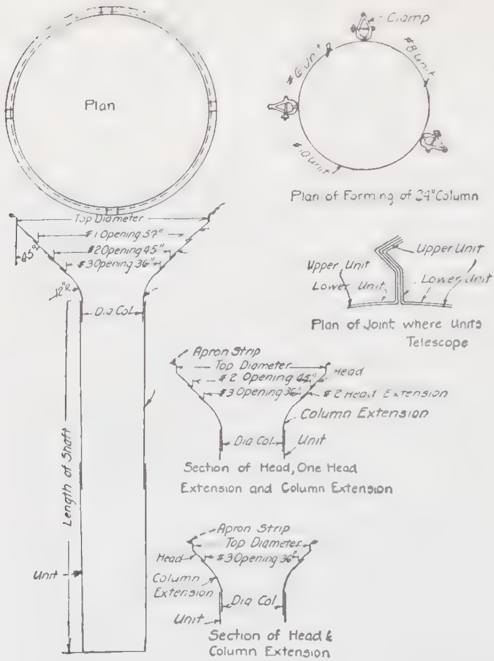


Fig. 50.—Hydraulic Pressed Steel Co. steel column forms.

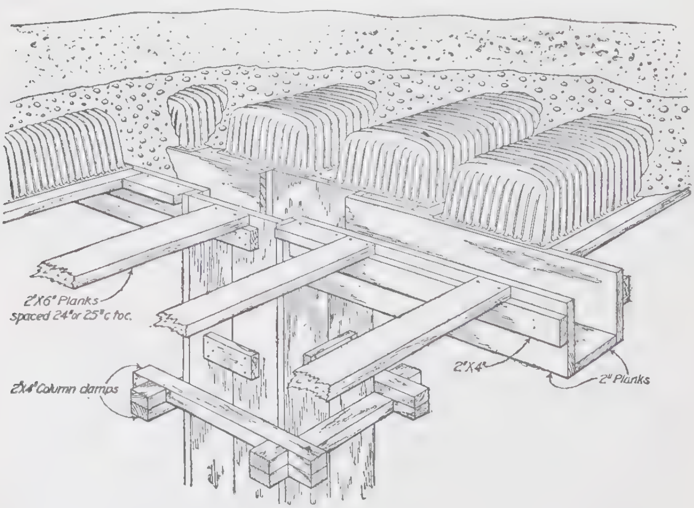


Fig. 51.—G. F. steel tyle.

sections. Adjustment in diameter is provided for by use of form panels of different widths.

Metal floor forms are of two types, removable and non-removable. These forms are usually made of pressed steel, and come

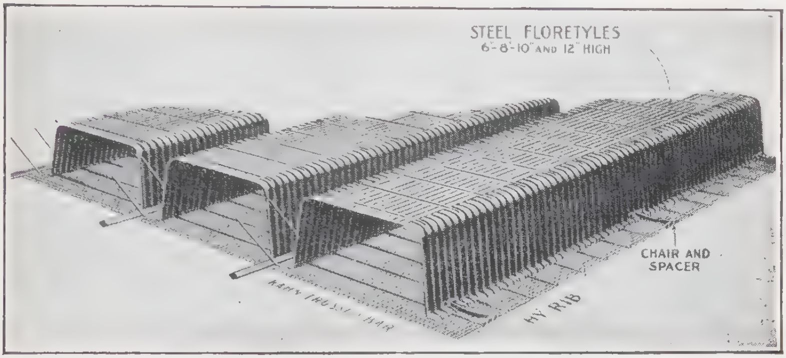


Fig. 52.—Steel floretyles.

in standard widths. The lengths may be fixed, or may be made adjustable by telescoping one section on another. Some of the removable types of metal floor forms are the Meyer Steel Forms, Berley Floor Cores, and Wiscoforms. In the non-removable types of steel floor forms, the steel forms take the place of hollow tile in the floor. Some of the types are G. F. Steel Tile, Steel Floretyles and Floredomes. The pressed steel is often ribbed or corrugated, to provide greater stiffness and rigidity. Metal floor forms usually come in depths of 6, 8, 10, 12, and 14

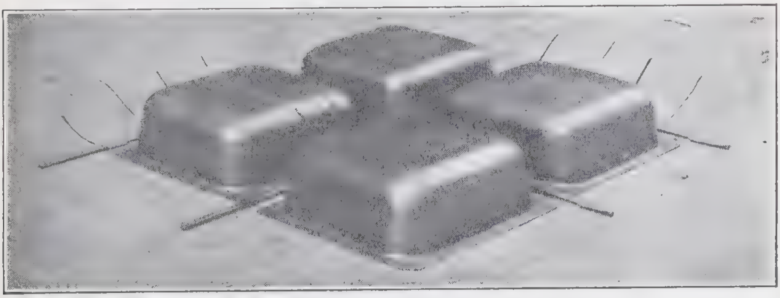


Fig. 53.—Steel floredomes.

in., and the width and length vary with different styles and different companies. Removable forms are usually well oiled before the concrete is formed, while non-removable forms are not.

Special metal forms are used for the construction of sewers, tunnels, etc.

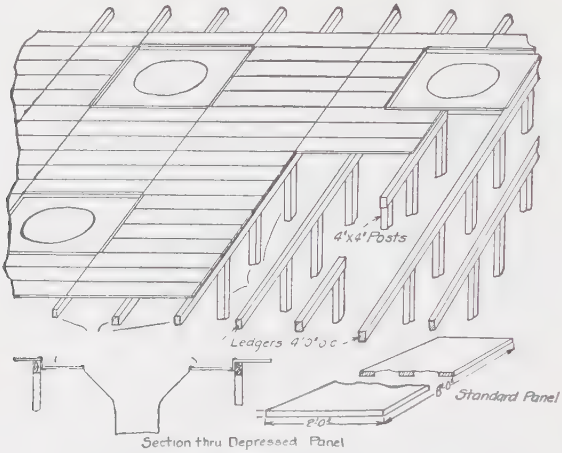


FIG. 54.—Metal panel forms for flat slab floor.

Exercises.—Describe one type of metal wall form.

Why are metal forms used more often than wooden forms, for round columns with flaring heads?

JOB 28. REMOVAL OF FORM MARKS AND MECHANICAL SURFACE FINISHING

In general, the treatment of the exposed concrete surface depends upon the results that are desired. In many buildings and bridges, not only are the form marks removed, but the surface is finished so as to improve the architectural appearance of the structure. In case of the floors, it is sometimes desirable to improve their wearing qualities.

The form marks can be reduced considerably by constructing the forms so that their inner surfaces are true, smooth, and tight, and then spading the concrete when it is placed in the forms, so that air pockets are eliminated, the coarse aggregate is forced away from the forms, and a thin layer of compact mortar is next to the form surface.

Common form marks are fins, edges, blemishes, and wood graining. Fins may be easily removed with a hammer and chisel. Edges may be removed by the same means, but require more and careful labor. Blemishes and wood graining may be

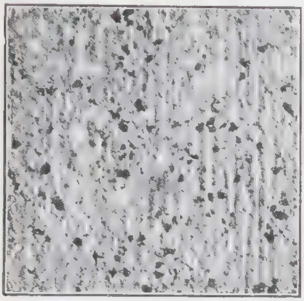


FIG. 55.—Fine textured concrete surface obtained by cutting.

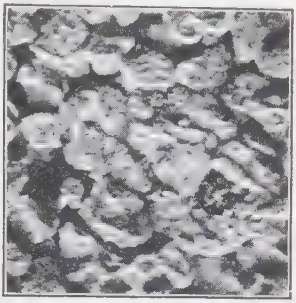


FIG. 56.—Machine made concrete block with coarse limestone, no facing mixture, and very little sand and cement.

ground off, or may be concealed by brushing with a thin, neat, cement grout. Holes caused by bolts, washers, wires, etc., may be filled with a mortar of the same proportions as that used in the concrete. When portions of the surface are honeycombed,

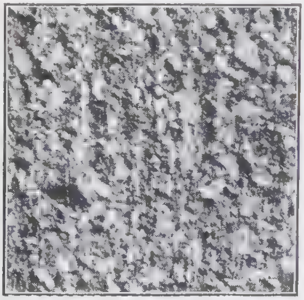


FIG. 57.—A cut concrete stone surface.

FIG. 58.—Tooled surface of concrete trim stone.

about the best method of treatment is to cut out the honeycomb and replace it with good concrete.

The more common methods of mechanical surface finishing are washing, acid treatment, brushing or scrubbing, rubbing, tooling, sand blasting, and sand float.

In the washing treatment, the outer film of cement and sand is removed by use of a stream of water before the concrete has set. This treatment is rarely used, because of the danger of leaving

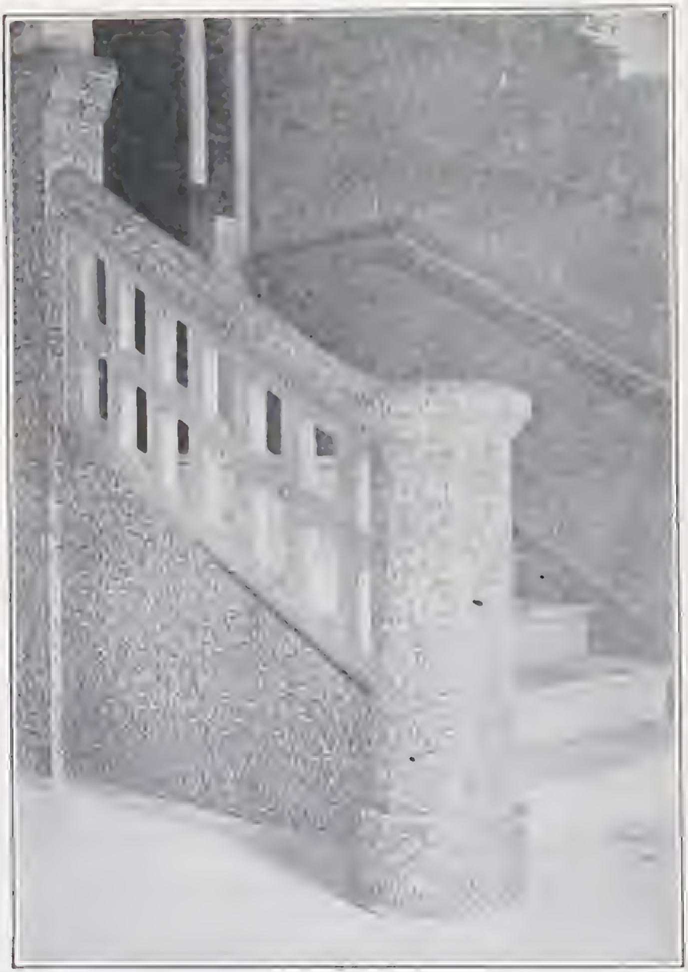


Fig. 59.—Special surface finish. Concrete rubbed and polished.

the green concrete unsupported before it has set. Washing should be done in from 6 to 8 hrs. after the concrete has been poured.

Scrubbing or brushing consists of brushing the surface of the concrete as soon as the concrete has set enough to hold the particles in place. An ordinary stiff wire or bristle brush used with a firm, even pressure gives uniform results. Water should be used, when brushing, to wash off the surface. The time required for hardening before brushing varies from about 24 hrs. in summer to several days in cold weather. If the coarse aggregate is to be exposed, then it should be spaded towards the form surface when the concrete is poured.

Acid washes are often used in connection with brushing to improve the appearance of the surface. The acid tends to eat away the cement from the surface of the sand and stone and, consequently, the treated surface must be thoroughly washed to remove all traces of the acid. The acid solution is made by mixing 1 part of hydrochloric (muriatic) acid with from 4 to 8 parts of water. A 1:8 solution is strong enough for very green concrete, while a 1:4 solution, together with vigorous brushing, may be required after the concrete has hardened.

Rubbing the wetted concrete surface, as soon as the forms are removed, with a fine-textured brick, soft stone, carborundum, emory, or other abrasive material will give a smooth surface of uniform appearance. If a rubbed surface is planned, the coarse aggregate should be well spaded back in the forms, when the concrete is poured. For best results, the forms should be removed in 1 or 2 days (in warm weather).

After the concrete has been thoroughly hardened, it can be tooled, hammered, crandaled, or ground, until a surface of uniform appearance is obtained. The coarse aggregate should be spaded back when the concrete is placed in the forms. Tooling permits of a variety of pleasing surface finishes, and need not be done until the concrete is 2 weeks old or older.

Sand blasting gives a pleasing appearance, but this method is not economical unless there is a large amount of comparatively unbroken areas to be treated. The concrete should be thoroughly hardened (at least 1 month old or more). All air pockets or depressions should be first repaired, and all fins, edges, and blemishes removed by tooling, as the sand blast affects the surface uniformly. Corners and angles must be protected if their sharp outlines are to be kept. A ¼-in. nozzle, a nozzle pressure of

from 50 to 80 lb., and a clean, sharp, dry silica sand passing a No. 8 sieve will usually give good results.

In the sand-float method of finishing, the forms must be removed before the concrete has fully hardened, and the surface must be rubbed with a wooden float with a uniform circular motion. Fine sand should be added and rubbed into the concrete surface until the surface has a uniform texture and appearance.

Exercises.—State the five classes of surface finishes.

How may form marks be removed?

Name five methods of mechanical surface finishing.

Describe the acid wash method.

Describe one form of surface finish by tooling (brush, hammering, crandaling, etc.).

JOB 29. USE OF COLORED AGGREGATES AND PIGMENTS

A very pleasing and satisfactory surface appearance may be obtained by the use of colored aggregates in the concrete mix. The successful production of the surface depends on the correct grading, proportions, mixing, placing of the concrete, and upon the method of finishing the surface. When these aggregates are expensive, they are used in a facing mixture, which is usually 1 or 1½ in. thick. A good method is to divide the form with iron plates, and pour the facing and backing together, gradually raising the plates as the molds or forms are filled. The proportions of the facing mix commonly used are 1 part of cement to 1½ parts of sand to 3 parts of pebbles or screenings by volume. Portland cement (common or white), white sand, marble chips, granite screenings, mica, slag, feldspar, and garnet sand are sometimes used. When the mix has hardened sufficiently, the surface is brushed or sprayed with water to remove the surface cement and expose the aggregates. An acid wash may be used when the acid will not affect the color and luster of the special aggregates.

Mineral colors or pigments (up to 6 per cent by weight of the cement and carefully mixed dry with the cement) may be used to give color surfaces. If there is much danger of the pigments reducing the strength of the cement, the colored mix should be applied as a veneer, as described in the previous paragraph. The yellows, browns, reds, and blacks produced by iron oxides

give permanent color, while the blues and greens may fade. Chromium oxide will give a permanent green. The correct amount of coloring matter to be added will depend partially upon the aggregates used, and may be found by experimentation. The following table, from Sabin's "Cement and Concrete," gives an idea of the amount of coloring matter required:

COLORING MATTER REQUIRED BASED ON A 1:2 MORTAR

Material	Color produced by ½ lb. per 100 lb. of cement	Color produced by 4 lb. per 100 lb. of cement
Lamp black	Light slate	Dark-blue slate
Prussian blue	Light-green slate	Bright-blue slate
Ultramarine blue	....	Bright-blue slate
Yellow ochre	Light green	Light buff
Burnt umber	Light pinkish slate	Chocolate
Venetian red	Slate, pink tinge	Dull pink
Red iron ore	Pinkish slate	Light brick red

Concrete surfaces may be painted by a number of good paints, which have been placed on the market for that purpose. The surface should first be primed with a solution of magnesium zinc fluosilicate or zinc sulphate in water, or with a commercial floor hardener, to aid in keeping the paint from peeling off.

Exercises.—What colors would be given to a concrete surface by using mica as a fine aggregate? Slag? Feldspar? Garnet sand?

How many a veneered surface be applied to a concrete block?

JOB 30. PREPARATION OF WEARING SURFACES

Wearing surfaces, such as concrete floors, require a special preparation and treatment, if they are to be satisfactory, and wear and dust reduced to a minimum. In general, the mix of which the average concrete floor is made will not give a good wearing surface, because of too lean a mix, too wet a mix, too much or too little tamping, excessive troweling, use of aggregates having a low abrasive resistance, and presence of laitance.

An old concrete floor which is not satisfactory in regard to wear and dust may be improved by one of three ways: (1) grinding the surface to remove laitance and loose material from the surface; (2) painting with special paints; and (3) roughing the old surface and applying a wearing coat at least 1 in. thick. In the third method, the old surface is roughened, cleaned, washed, and thoroughly wetted, and then a neat cement grout is applied, followed by a wearing course mix before the cement grout has attained initial set.

A new concrete floor can be satisfactorily made in regard to wear and dust, if the aggregates used have a high abrasive resistance, and have been screened and washed. The mix should not be leaner than 1 part of portland cement to 2½ parts of aggregate, and the least amount of mixing water that will produce a dense mix should be used. The materials should be mixed thoroughly, carefully placed and tamped (but not too much), the surface screeded even, and finished with a wood float without excessive troweling. Any excess water should be immediately drained or otherwise removed. The surface should be kept wet for at least 10 days in the case of floors, and then ground with a surface-grinding machine.

It is usually more satisfactory to construct the floors in two courses, base and wearing. The base course is laid as in any concrete work, and the wearing course added within ½ hr. after the base course is placed. The wearing course must be at least 1 in. thick, and of a mix not leaner than 1:2½ by volume. Screened and washed aggregates having a high abrasive resistance should be used. The floor surface should be kept wet for at least 10 days after placing, and then ground with a surface-grinding machine.

"Granolithic finish" is a term frequently applied to a concrete wearing surface which contains crushed granite or other hard stones as an aggregate, and which has been usually ground by means of a grinding machine.

Terrazzo finish may be made by either one of two methods. One method is to use a mix of 1 part of portland cement and 2½ parts of crushed marble (or other stone as specified), and enough water to produce a dense concrete. This concrete is spread on the base course, and worked down to a thickness of not less than

1 in. by patting or rolling and troweling. The marble should pass a ½-in. screen, and be clean and free from dust. After being kept wet for 10 days, the surface may be ground to a plane surface with a surface-grinding machine. When finished, the surface should show about 95 per cent of hard aggregates and 5 per cent of cement.

The other method of making a terrazzo finish is to mix 1 part of portland cement and 2 parts of sand and enough water

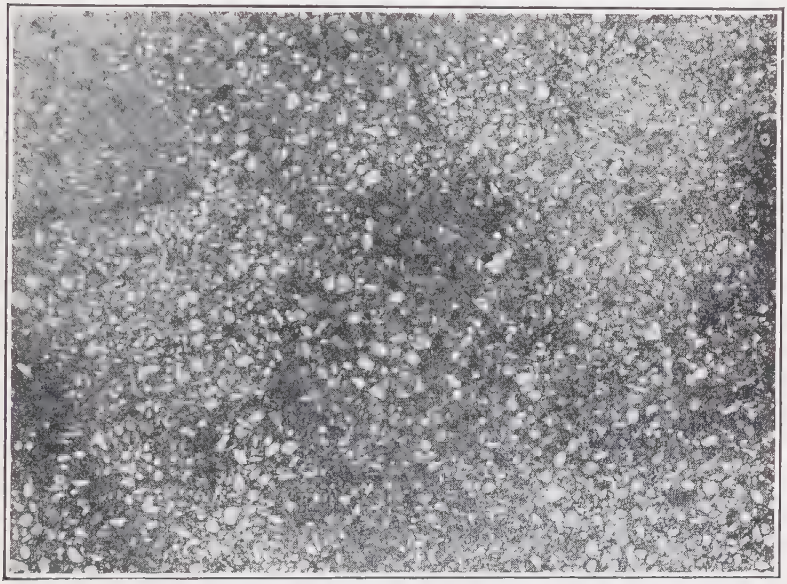


FIG. 60.—Close up photograph of terrazo wearing surface.

to produce a plastic mortar, which is spread on the base course to a depth of not less than 1 in. Clean, dust-free, crushed marble passing a ¼-in. screen is then sprinkled over the fresh mortar surface and pressed or rolled in. After the surface has been kept wet for at least 10 days, it is finished with a surfacing machine.

A terrazzo finish may be applied to an old concrete floor prepared as described above.

Many pleasing effects can be obtained by using colored aggregates, such as red granite chips, feldspar, and colored marbles

and pigments. In many instances, tile patterns have been inlaid in concrete floors with satisfactory results.

Painting is satisfactory, when the wear is not great. The paint may be prevented from peeling by using a priming coat of zinc sulphate solution (8 lb. of zinc sulphate to a gallon of water). Oiling floors has sometimes been successful in preventing dust when the traffic is light.

Exercises.—What is a granolithic finish?
What is a terrazzo finish?
Describe one method of making a terrazzo finish.
Why should the wearing surface be 1 in. thick or more?
What is the object of grinding a floor?
What kind of aggregates tend to make a good wearing surface?

JOB 31. CONCRETE BUILDING UNITS

The concrete products industry has grown slowly and surely, and is now a substantial part of the whole concrete industry.

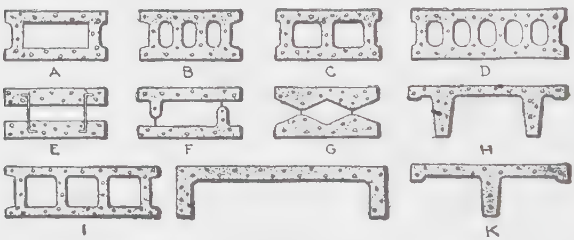


FIG. 61.—Horizontal cross sections of representative types of concrete block.

Many of the early blocks made were failures, due to poor machines, wrong materials, incorrect proportions and consistencies, lack of skill in molding, improper curing, and wrong shapes and sizes. In the last few years, the concrete block industry has progressed, due to the increase in skill and experience of the workers, and the aid of the cement and machinery manufacturers.

There are two main divisions in the concrete products industry: (1) the production of standard building units in quantity; and (2) the manufacture of trim stone, blocks, and brick with special ornamental facings, and specially molded ornamental work.

The concrete blocks are of various sizes and arrangements of walls and cores, though practically all of them provide for hollow air spaces. The front and rear walls of the block may be tied together with concrete or metal ribs, the use of metal preventing the passage of water through the block. In some instances, the blocks are designed so that the wall thickness is made up of two or more blocks, so as to give a discontinuity of concrete through the wall. Figure 61 shows the cross-sections of various types of concrete blocks. The dimensions of the standard blocks vary, being from 7¾ to 12 in. thick, from 8 to 12 in. high, and from 15¾ to 32 in. long. The 7¾- × 8- × 15¾-in. size is the most common.

Concrete building tile vary from about 5 in. high × 3 in. wide, and 12 in. long to 12 in. high, 12 in. wide, and 32 in. long. Concrete brick are made in various sizes, the most common being 2¼ in. high, 3¾ in. wide, and 8 in. long.

The Bureau of Standards recommends the following sizes of concrete building units:

Concrete Block

Height, inches	Tolerance, inches	Width, inches	Tolerance, inches	Length, inches	Tolerance, inches
7¾	minus ⅛	6	minus ¼	15¾	minus ⅛
7¾	minus ⅛	8	minus ¼	15¾	minus ⅛
7¾	minus ⅛	10	minus ¼	15¾	minus ⅛
7¾	minus ⅛	12	minus ¼	15¾	minus ⅛

Concrete Brick

Kind	Height, inches	Width, inches	Length, inches
Face and common.............	2¼	3¾	8

Concrete Building Tile

Kind	Height, inches	Width, inches	Length, inches
Load bearing	5	3¾	12
	5	8	12
	5	12	12
Partition	3	12	12
	4	12	12
	6	12	12
	8	12	12
	10	12	12
	12	12	12

A plus or minus tolerance of 3 per cent is permissible in each of the three dimensions of concrete building tile.

The materials used, in the manufacture of concrete building units, are portland cement, and fine and coarse aggregates. In general, materials suitable for first-class concrete work are also suitable for making concrete building units, except that the maximum size of the aggregate rarely exceeds about ½ in. and should always be less than half of the smallest dimension of the block, brick, or tile. For special surfaces and finishes, various kinds and types of aggregates are used like those mentioned in previous jobs describing ornamental finishing of concrete surfaces.

The proportions used for the mixes vary from about 1:3:4 to 1:1:1½ by volume, depending on the qualities of the aggregates and the specifications to be met. Some of the larger manufacturers are now proportioning their mixes according to the latest scientific methods.

The mixing may be done either by machine or by hand. Machine mixing is preferred.

The molding may be done by hand or machine, except that a machine is required in the pressure process. Concrete standard building units are usually machine molded, while concrete stone trim are hand molded. At present, there are various molding machines on the market. The construction of the machines varies with the consistency of the mix, the method of compacting the concrete, and the ideas of the manufacturer.

The following three methods are commonly used in the manufacture of standard concrete building units:

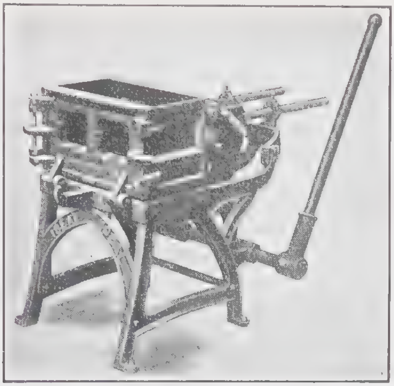


Fig. 62.—Hand tamp concrete block machine.

1. *Dry Tamp Process.*—The materials are mixed to a damp consistency, and are then tamped in the molds by hand or machine tampers. Care should be taken not to get a consistency

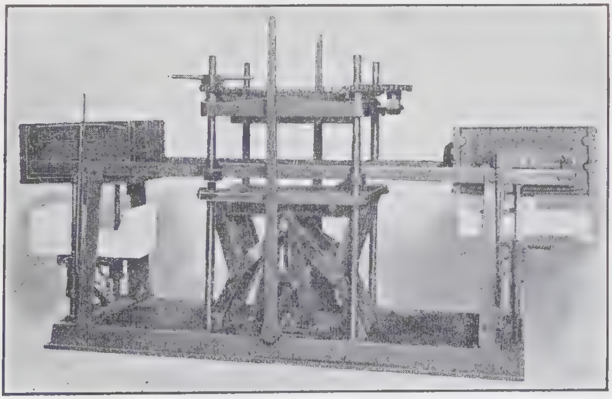


Fig. 63.—Pressure concrete block machine.

which is too dry. This method is frequently used to make concrete stone of special shape or surface finish, because the molds may be of any desired shape and size.

2. *Pressure Process.*—A somewhat wetter consistency is used than in the dry tamp process. The mixed concrete is placed in the molds and compacted by pressure, applied either by mechanical levers or a hydraulic piston.

3. *Wet Cast Process.*—In this process, the consistency should be such that the concrete will flow readily. The mix is poured in the molds, and puddled or rodded to remove the air and to get the larger particles away from the sides of the molds. No tamping or mechanical pressure is used. Frequently, the consistency is made too wet for the best strength results.

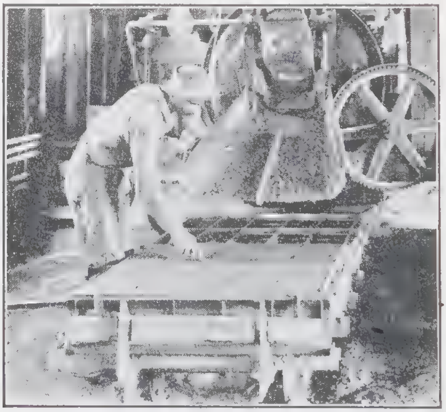


Fig. 64.—Metal gang molds mounted on car.

In the first two processes, the concrete is so dry that the molds can be removed at once from the blocks, while in the last method the molds cannot be removed until the concrete has attained hard set. In all three processes, care should be taken to secure density and uniformity of the concrete.

In curing, care should be taken to prevent the too rapid drying out of blocks. After the molds are removed, the blocks and brick should be protected from wind currents, sunlight, dry heat, and freezing for at least a week. During this time, the blocks should be thoroughly sprinkled at least once a day. After the first week the blocks should be sprinkled, or otherwise moistened occasionally, until they are used. When cured by any natural

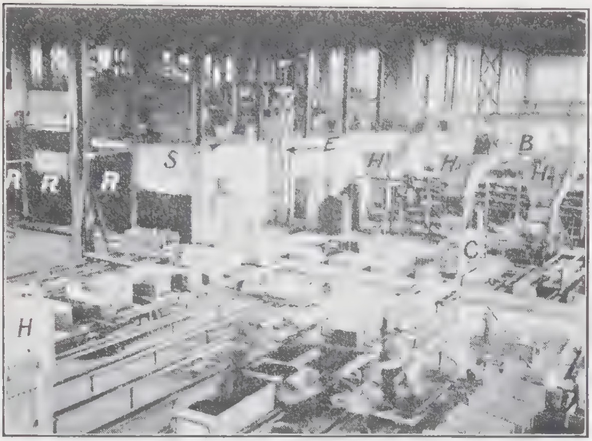


Fig. 65.—Concrete products factory. (Block department in background.)

R = Curing rooms.
S = Second floor (or intermediate floor above curing rooms) where a battery of five mixers are located.
E = Elevator for boxes of mixed facing material.
B = Bucket (a part of an electric monorail system) for delivering mixed concrete to machines and at bankers.
H = Hoppers to receive mixed concrete.
C = Block car.

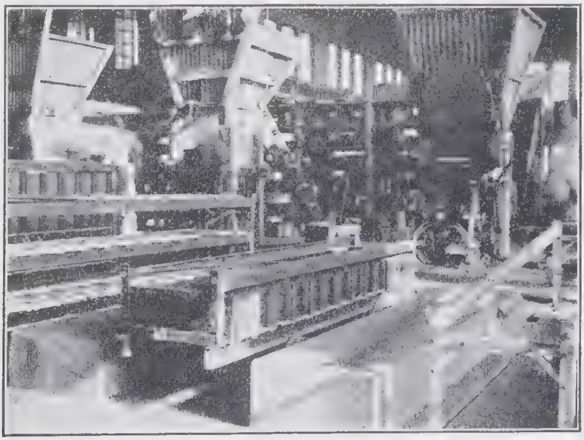


Fig. 66.—Part of concrete block department of a concrete products factory. Block machines with hoppers above are shown in the background and block cars in the foreground. Note the two floor levels. The cars run on tracks into pits so that four decks can be loaded without too high a reach. The empty "decks" from the car at the left are placed on the car at the right as it is piled.

process, concrete building units preferably should not be used until they are 28 days old.

The curing of concrete building units may be hastened by placing them for at least 48 hr., when they are removed from the molds, in an atmosphere of moist steam. The temperature of the curing room should preferably be from 100 to 130°F. The saturated steam provides heat and moisture, and accelerates the hardening of the concrete. After removal from the steam-curing room, the building units should be stored for a week before using.

Concrete building block and tile should pass the American Concrete Institute Standard Specifications for Concrete Building Block and Building Tile (Serial Designation P-1A-25) given in Appendix 11. It should be noted that these concrete building blocks and tile are divided into heavy-load-bearing, medium-load-bearing, and non-load-bearing units, according to their unit compressive strength. Concrete building blocks and tile that are not to be exposed to the soil and weather are not required to pass the absorption test. The average unit cross-bending strength (modulus of rupture) of concrete building blocks, tile, and brick will be about 10 per cent of the average unit compressive strength.

Concrete building brick should pass the American Concrete Institute Standard Specifications for Concrete Brick (Serial Designation P-1B-25) given in Appendix 12.

Concrete building units are being used at an increasing rate in all parts of the country. Some of the more common uses are basement walls, walls for stores, residences, barns, silos, etc., partitions, and in most any place when a light, durable, fireproof wall or partition is desired.

Exercises.—What are the differences between concrete building block, tile, and brick?

What are the compressive strength requirements of concrete building block and tile? Of concrete building brick?

What are the absorption requirements of concrete building block and tile? Of concrete building brick?

A compressive test on concrete building block gave the following results: 1215, 1017, 835, 727, and 971 lb. per sq. in. In what class do these blocks belong?

JOB 32. CONCRETE TRIM AND ORNAMENTAL STONE

There are special machines on the market for molding different special concrete units, as well as a large number of special molds

for sills, lintels, balusters, belt courses, cornices, and other trim stone, and various architectural pieces. In addition to these special machines, it is necessary for the concrete products manufacturer to have skilled workmen to make intricate designs of concrete stone to meet the demands of the architects.

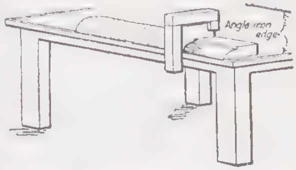


FIG. 67.—Making plaster molding.

Most of the molds for concrete dimension stone (sills, lintels, belt courses, cornices, etc.) are constructed of wood, preferably white pine. For simple work, the mold consists of side planks and end pieces resting on a pallet, and held together by clamps. In dry cast work, the facing mixture, if one is used, is placed in the bottom of the mold, up to the front, and part-way up the ends, as desired, and then the backing mixture is added and

FIG. 68.—Plaster molds. The dark modeled part is the plaster model. The parts A and B are the first two pieces of a plaster mold.

tamped in place. The concrete is struck off smooth at the top, a layer of bedding sand added, and a plank placed on top of the sand and clamped in place. The entire mold and contents are turned over, so that the concrete stone is right-side up when the mold is removed. When the concrete has hardened sufficiently, the mold pieces are removed, and the concrete stone left right-side up on

the plank. A very dry consistency is used, as the molds are removed after a short time.

In the wet cast method, a smooth concrete floor or table top is shellacked and oiled, and the form pieces erected thereon, with the necessary insert pieces and partitions. A concrete of rather wet (quaky) consistency is used, and the concrete stone left in the molds until it has thoroughly hardened.

Various metal molds are now made for different ornamental pieces and standard architectural units. These molds need only to be cleaned and oiled, and can be used many times.

When necessary, the individual stones (such as lintels) may be reinforced against bending.

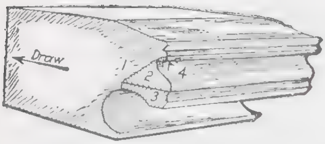


FIG. 69.—Splitting pattern for making sand mold.

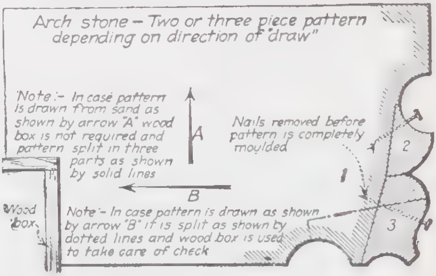


FIG. 70.—Two ways of splitting a pattern.

Plaster is used quite extensively for making models and molds for ornamental concrete stone. Skilled workmen can make a suitable plaster mold from the architect's drawings. When the plaster model is finished, it is shellacked and oiled, and a mold made over the model. The model is removed from the mold, and the mold surface shellacked and oiled before the concrete is added. With plaster molds, the concrete mix is quite dry, and is lightly but firmly tamped in the mold. Draw molds may be used when there is no undercut, and when the undercut sections of the mold are made so that they will readily separate from the main part, and can be removed easily after the main part of the mold had been drawn. Drawn molds must be smooth and true, and tapered a little, so that they can be withdrawn without injuring the concrete. Plaster molds may be used several times.

Gelatin or glue molds should be used where there is much undercut, which would necessitate making the plaster mold in many pieces. In making a glue mold, the model mold is first covered with paper, and a thin layer of modeling clay added. This clay covering is greased, and plaster added over it, to form a shell with several holes and air vents. When the plaster mold is hard, it is removed, and the clay and paper cleaned from the model. The surfaces of the model and mold are shellacked and oiled, the model is placed in the mold, and the space between them filled with hot glue. The air vents can be stopped with clay as the space is filled. When the glue is hard (requiring about 24 hr.), the plaster mold is first removed, and then the glue mold is cut into a few parts and removed from the model. The consistency of the concrete used with a glue mold is wetter than that used with a plaster mold, because concrete cannot be tamped in a glue mold. A glue mold may be used about four times, after which the glue may be remelted and used for another mold.

Sometimes various combinations of molds are used, such as wood strips in plaster molds, plaster inserts in wood molds, and small glue molds in connection with plaster molds. For difficult ornamental work, when much duplication is necessary, a glue mold is first made, then a glue model, and then several plaster molds from the glue model. When the work is intricate with much undercut, the plaster mold is cut away from the concrete and "wasted," no attempt being made to save the plaster mold for re-use.

Sand molds are made by packing sand around models in core boxes, in about the same manner that molds are made for iron castings. The sand should be a fine sand which will mold well. The sand is wet to make it slightly damp, and it is often mixed with fine loam or plaster, and sometimes with an integral waterproofing powder. After the molding sand has been packed around the models, the models are removed or withdrawn, and the mold filled with concrete of a flowable consistency. Excess water should be avoided whenever possible. The sharp edges in the mold may be built up of wood inserts, as the sand edges may crumble. Draw molds may be used in connection with sand beds, if care is taken in the design of the draw mold, to taper it

and provide removable inserts, when there is undercut. As the sand tends to stick to the concrete surfaces, it is nearly always necessary to give the concrete stone some surface treatment.

Although most concrete block and dimension stone are made of the same mix and material throughout, it is very easy to provide facing mixtures, especially in the dry tamp method. Previous jobs describe various methods of making and surface finishing to secure different ornamental surfaces, which methods may be used in connection with concrete ornamental and trim stone. Colored effects may be produced by the use of good mineral pigments, as previously described.

Exercises.—Name the various methods of molding concrete trim and ornamental stone.

Described, with a sketch, the making of a simple wood mold for a concrete lintel.

SECTION III

CONTRACTS, SPECIFICATIONS, AND PLANS

JOB 33. CONTRACTS

A contract is an agreement, usually based upon a consideration, to do or not to do some particular thing which the law will enforce.

A contract for construction work should be in writing. A complete contract will include the following documents: advertisement or notice to contractors; information for bidders; form of proposal; general contract; bond; general specifications; detailed specifications; and plans and drawings.

On some jobs, part of these documents may be omitted. For example, if one man contracts with another to build a house, perhaps only the general contract, general and detailed specifications and plans would be needed.

A general contract should include the following: introduction of agreement and date; name, description, and residence of parties; statement of agreement; list of documents included in contract; time of beginning and completion; payments—time and amounts; liquidated damages; provision for bond; and final clauses, date, signatures and seals of parties, signatures of witnesses, and acknowledgment.

There are several kinds of construction contracts, such as lump sum, unit price, cost plus percentage, cost plus fixed or varying fee contracts. A lump sum contract is one in which the contractor agrees to do the work for a certain definite sum. In a unit price contract, as in excavation, the contractor agrees to remove the earth for a certain price per cubic yard. The cost plus percentage contract is one in which the contractor receives the cost of the work plus a percentage of the cost for profit. Another form of contract is the cost of the work plus a fixed fee or profit, so that the amount of the contractor's profit is the same regardless of variation in cost. Perhaps a more satisfac-

tory form is one in which the contractor receives the cost plus a fee or profit, which profit will be decreased if the cost is more than an agreed sum or vice versa.

JOB 34. STANDARD BRIDGE CONTRACT

The Wisconsin Highway Commission's Standard Bridge Contract will usually include the following: (1) advertisement and notice to contractors; (2) proposal for bridge work including instructions to bidders and proposal; (3) contract; (4) bond; (5) specifications including general and detailed specifications; and (6) plans.

In this job, the standard form of instructions to bidders, proposal, contract, and bond follow in order. Sample standard specifications and plans are given in following jobs.

The advertisement usually does not conform to any standard form, but is written for each individual job and published as required by the laws of the state in which the job is located. An advertisement should contain the following information, though some of the items are sometimes included in the instructions to bidders:

1. When, where, and by whom bids will be received.
2. Location of work.
3. Amount and nature of work or material to be furnished.
4. Time of beginning and time of completion of work.
5. Where plans and specifications may be seen or obtained.
6. Where, and from whom, general information may be obtained.
7. What security will be required with the proposal.
8. What security or bond will be required with the contract.
9. When and where bids will be opened.
10. When and where contract will be awarded.
11. Reservation of right to reject any or all bids.
12. Official signatures of officials receiving bids or letting contract.

In all public work, the laws require that certain formalities be observed when advertising the work, receiving bids, and letting the contract. The contractor should note if all of the legal requirements have been met.

In private work, many of the formalities required in public work may be (and usually are) dispensed with. The advertisement may be omitted, the number of bidders may be restricted, the wording of the contract may be changed to suit the individuals concerned, the bond may not be required, etc.

PROPOSAL FOR BRIDGE WORK

Instructions to Bidders

Proposals may be made on reverse side of this form or on other convenient form, but must refer to, and be in accordance with, the plans and specifications on file, otherwise, they may be rejected as irregular. Only sealed bids will be considered. The right is reserved to reject any or all proposals and to accept any bid which may be most advantageous to the party of the first part.

Proposals should be addressed to the Board of Supervisors of the Town, Village Board of the Village, or County Highway Committee of the County named as party of the first part in the contract, and be accompanied by a certified check for a sum equal to at least 5 per cent of the bid as a guarantee that the successful bidder will enter into a contract with the party of the first part, and will give a good and sufficient bond in a penal sum equal to the amount of the contract for the faithful performance of the work. Said guarantee shall be made payable to the Treasurer of the said Town, Village, or County. This guarantee will be returned to the bidder, unless, in case of the acceptance of his proposal, he shall refuse to execute a contract and file a bond as required in the specifications, within fifteen days of the acceptance of the proposal, in which case the guarantee is to be considered payment for damage due to delay and other cause suffered from refusal or neglect to execute a contract, and shall become the property of the said Town, Village or County.

Unless special instructions are issued specifying otherwise, all bids shall be a lump sum proposal for bridge complete, including superstructure and substructure. When superstructure and substructure are required to be itemized, the right is reserved to accept any bid for superstructure, and to use this in connection with any bid for the substructure alone. No award of substructure alone will be made on any itemized bid, unless bidder specifies that such award will be acceptable. All proposals made on bidder's forms should state a specific sum of each of the items A, B, C, D, and E, but any repetition beyond specifying the item by letter and the sum bid therefor, is unnecessary.

The plans and specifications are designed to be correct and consistent. Bidders must, however, examine, not only the plans and specifications but the bridge site as well, thoroughly and carefully, and submit bids on their own responsibility. Any estimate of quantities, which may be given either on the plans or otherwise, is believed to be accurate but its accuracy is not guaranteed and bids must be made on bidder's own estimates.

PROPOSAL

To the ....

....

Gentlemen:

The undersigned proposes to do the bridge work on the............................
Bridge in the..................of..County, for
and in consideration of the sums hereinafter specified.

Item A

Complete .... consisting of

....

....

for the sum of .... Dollars $ ....

....

Item B

Any additional concrete masonry in the substructure of the same classification as on plans at no greater depth than shown on plans, if ordered, for.............................. Dollars ($..........) for each cubic yard in excess of the quantity shown on the plans.

Item C

Any additional concrete masonry in the substructure of the same classification as on the plans at depth greater than shown on plans, if ordered, for............................ Dollars ($..........) for each cubic yard in excess of the quantity shown on the plans.

Item D

If the quantity of concrete masonry required in substructure is ordered reduced, the undersigned hereby consents to a reduction of................................ Dollars ($..........) from the contract price for each cubic yard the quantity shown on plans is so reduced.

Item E

Any additional piling not shown on plans, if ordered, for........................cents (..........c), for each linear foot delivered on the work, plus....................cents (..........c) for driving for each linear foot for actual penetration.

The above prices include furnishing the bridge work complete in place, including all materials, tools, machinery, labor, necessary forms and falsework, steel reinforcement and piling where shown on plans, doing all excavation, removing the existing structure or structure replaced, and any other work which may be necessary in order to do the work included in each item for which price is specified, in full conformity with the plans and specifications and the requirements of the Engineer.

The undersigned declares that he has examined the bridge site, the plans the specifications for the work for which this proposal is made, to his full satisfaction, and that if proposal is accepted he will execute a contract and file bond as provided in the specifications.

Signed....................................

....

....192..

CONTRACT

This Agreement, entered into this .... day of .... , 192 .., by and between .... County, Wisconsin, represented by its County Highway Committee, party of the first part, and

....

of.., party of the second part.

WITNESSETH, That for and in consideration of the payments to be made by said party of the first part, hereinafter called the County, to said party of the second part, hereinafter called the Contractor, said Contractor hereby agrees to do, at his own proper cost and expense, all the Highway Bridge Work on that portion of the County System of Prospective State Highways in the .... of ...., in said County, which is shown on plans and specifications annexed hereto, and made part hereof, in full conformity therewith. The said Contractor agrees further to begin work on or before.................., 192.., to complete same not later than.............., 192.., and to keep the road..............to travel during construction.

....

....

And said County, in consideration of the full and complete performance of said Highway Bridge Work by said Contractor, hereby agrees to pay, in the manner provided in the specifications, to said Contractor, the sums specified in the proposal submitted by said Contractor, which proposal is hereto annexed and made part hereof.

The Contractor shall pay all claims for the performance of any work or labor of the furnishing of any materials when the same pertains or is for or in or about or under this contract as required by Section 289.16 Statutes of Wisconsin, and shall have paid and discharged all liabilities for injuries which have been incurred in the said construction, under the operation of sections 102.01 to 102.34 of the Statutes of Wisconsin, inclusive, and all acts amendatory thereto.

....

....

....

....

IN WITNESS WHEREOF. The parties hereto have set their hands the date herein named.

Approved: ...., 192

..............................., County.
Party of the First Part

....
County Highway Commissioner

By

Approved: ...., 192

....
Division Engineer

Approved: ...., 192

....

.......................Engineer

....
County Highway Committee

Approved: ...., 192 .., for the
WISCONSIN HIGHWAY COMMISSION

....
Party of the Second Part
By

....
State Highway Engineer

....
(Give Title or Position)

CONTRACTOR'S BOND

KNOW ALL MEN BY THESE PRESENTS, That we, ...
. . . . of . . . .
as Principal, and . . . .
. . . . as Suret. . . ., are held and firmly bound unto . . . .
County, Wisconsin, in the penal sum of . . . .
. . . . Dollars ($ . . . . .), lawful money of the United States, to be paid to said County, for which sum of money, well and truly to be paid, we bind ourselves, our heirs successors, executors, and administrators, jointly and severally, firmly by these presents.

Sealed with our seals and dated this . . . . . . day of . . . . , 192

The condition of this obligation is such, that if the said bounden principal shall, in all things, well and truly perform all the terms and conditions of the within and foregoing contract to be by . . . . performed, and within the time therein mentioned, and shall pay to each and every person or party entitled thereto all the claims for work or labor performed or materials furnished for or in or about or under such contract as provided in Section 289.16 of the Statutes, and shall have paid and discharged all liabilities for injuries which have been incurred in the said construction, under the operation of Sections102.01 to 102.34 of the Statutes, inclusive, and all acts amendatory thereto, then this obligation is void; otherwise it shall be and remain in full force and virtue.

STATE OF WISCONSIN,

County of . . . .
. . . .
being first duly sworn, on oath says that he is worth the sum of . . . .
Dollars in property within this state, over and above all debts, liabilities and exemptions.
Subscribed and sworn to before me this
day of . . . . , 192

. . . .
Notary Public.

STATE OF WISCONSIN,

County of . . . .
. . . .
being first duly sworn, on oath says that he is worth the sum of . . . . .
Dollars in property within this state, over and above all debts, liabilities, and exemptions.

Subscribed and sworn to before me this . . . .
day of . . . . , 192

. . . .
Notary Public.

NOTE—When executed by personal sureties make foregoing deposition.

. . . .
Principal
By . . . .

. . . .
Surety

By . . . .
. . . .
In Presence of . . . .

. . . .

. . . .

NOTE—When executed by a Surety Company, attach to the bond certificates from the Insurance Department that Company is authorized to transact business in the State, and that agent is duly licensed at the time; also a valid power of attorney of person or persons executing bond for the Company.

The foregoing bond is hereby approved this . . . . . . day of . . . . , 192

. . . .
District Attorney

Exercises.—What is the object of including the items *B*, *C*, *D*, and *E* in the standard form of proposal?

Prepare a form of proposal for a concrete sidewalk based on a lump sum for the job, with possible additions and deductions at certain prices per square foot.

JOB 35. SPECIFICATIONS

The specifications of a construction contract refer to the details of the relations and obligations of the owner, engineer, and contractor, and to the details of the work and method of construction. The first part is called the general specifications

or general conditions of the contract, and the latter part is called the detailed or technical specifications.

General specifications include the following subdivisions.

1. Definition.

2. Rights of owner in regard to inspection and supervision, right of access to work, changes, alterations, extra work, discrepancies, omissions, etc.

3. Engineer's or architect's authority in regard to the work.

4. Method of making estimates and payments for regular and extra work.

5. Contractor's responsibilities in regard to himself and workmen, compliance with laws, protection against damages and claims for labor and materials, assignments, subcontracts, time of completion, rate of progress, liquidated damages, protection of work, defective work, delays, construction plants, sanitation, etc.

Detailed or technical specifications include clauses specifying the kinds and quantities of the materials and the methods of doing the work. For example, technical specifications for a concrete sidewalk would include clauses in regard to the excavation, foundation, drainage, forms, kind and quality of the cement, sand, and stone, proportions of mix, consistency of mix, method of mixing concrete, method of placing concrete, method of finishing the surface, protection from weather, disposal of surplus material, and cleaning up. If not stated in another part of the contract, the length, breadth, and thickness of the walk should be given.

When writing technical specifications, the first requisite is clearness. The words, phrases, sentences, and paragraphs should be so selected and arranged that there can be no uncertainty as to the meaning of the specifications. The use of ambiguous words and terms should be avoided.

Specifications should be brief, but clearness should not be sacrificed for brevity.

Indefinite, indeterminate, ambiguous, and arbitrary specifications are to be avoided, as well as specifications which are unfair to the contractor or owner.

Whenever practical, it is advisable to specify stock articles and sizes, as such are invariably cheaper than special articles

and sizes. Special brands preferably should not be specified, unless the bidder is given a chance to suggest other suitable brands.

A specification writer should be careful not to use parts of published specifications unless he is sure that these parts apply to the work contemplated. A study of published specifications is wise, but the blind copying of parts of these specifications for other work should be avoided.

In determining the requirements for certain materials, it is often satisfactory to require them to pass certain well-known standard specifications and tests. For example, the portland cement used should be such as will pass the requirements of the A. S. T. M. Standard Specifications for Portland Cement.

In regard to writing specifications for methods of doing work, it is usually more satisfactory to leave the choice of methods to the contractor and then hold him responsible for the satisfactory performance of the work. If the method is specified and the work then turns out unsatisfactorily after the contractor has followed this method, he (the contractor) may escape the responsibility for the poor work.

When writing specifications always examine each paragraph and clause to see if it represents good practice, if it applies to the work for which it is written, and if it is consistent and agrees in general with the other paragraphs and clauses with which it is to be used.

Exercises.—What are general specifications? What things do they include?

What are detailed specifications? What do they include?

Why is it sometimes not advisable to specify methods of doing work?

JOB 36. STANDARD SPECIFICATIONS FOR A REINFORCED CONCRETE HIGHWAY BRIDGE

The following specifications are general specifications for all highway bridge work, and detailed specifications for concrete in forms prepared and used by the Wisconsin Highway Commission.

Note that the general specifications have, on the first page, blank spaces, which are to be filled in with the name and general description of the job in question, and with a list of the plans included in the contract.

In the detailed specifications for Concrete in Forms there are several clauses which may not be needed for certain jobs. For example, if all concrete was to be of Class *A*, clauses relating to Classes *B*, *C* and *D* would not be needed. Also, if a deck girder bridge were to be built, clauses relating to slab bridges and arches would not be required.

WISCONSIN HIGHWAY COMMISSION

Specifications for the. . Bridge, over
located in between Sections
....County, Wisconsin,
being a part of contract annexed hereto.

The work to be done under the contract shall be................................

....

The plans mentioned in the contract are as contained in drawings prepared by the Wisconsin Highway Commission, and annexed hereto marked.............................

GENERAL PROVISIONS

1. Work.—It is understood that the work to be done includes everything which might reasonably be considered necessary for a complete and workmanlike job in accordance with the plans and specifications in every detail.

The Engineer will furnish and set survey stakes, or other marks at random distances from the center line of the contemplated roadway and furnish the contractor with a grade sheet showing the horizontal and vertical distances from said stakes or marks to the center of the roadway. The Contractor shall make such measurements, and set such stakes as may be necessary to begin work. He shall furnish all material, tools, machinery, labor and other means of construction to complete the work, including all excavation for foundations. He shall remove the structure existing at the site, or structure replaced by bridge mentioned in the contract, and pile the resulting material neatly on the bank. The excavations for foundations shall be according to the dimensions shown on plans and shall be carried to such depth as is necessary to secure good foundation free from all danger of damage from settlement, frost, or scour even though necessary to exceed the depth shown, but there shall be no variation in depth without a written order as hereinafter provided. All excavated material and other obstructions to the stream bed at any point between the ends of the wings of the abutments shall be removed and the channel left clear and unobstructed. This includes the removal of any dirt in the banks of the stream necessary to give clear opening. Material suitable for back filling shall be placed in the fill back of the abutments. All foundation excavations in front of abutments and piers shall be refilled, all rubbish removed, and the bridge left in a neat condition.

The Contractor shall notify the Engineer a reasonable length of time (not less than five days) in advance of the time when he expects to begin work. He shall give his personal attention to the work and shall not sublet the same without the consent of the Engineer. It is understood that good appearance and proper finish shall be considered as essential to the proper execution of the work.

Until acceptance of the bridge, it shall be under the charge and care of the Contractor, and he shall take every necessary precaution against injury or damage to the bridge, or to any part thereof, by the action of the elements, or from any other cause whatsoever, whether arising from the execution or from the non-execution of the work. The Contractor shall rebuild, repair, restore and make good at his own expense, all injuries or damages to any portion of the bridge occasioned by any cause before its completion and acceptance.

2. Time of Completion.—It is understood that the Contractor shall begin work at a reasonable length of time in advance of the time named for completion, and prosecute the work with reasonable dispatch until the work is finished.

If the Engineer believes that the work is unnecessarily delayed, he shall notify the Contractor and his sureties to the effect, in writing. If the Contractor, or his sureties, does not then, within ten days, take such measures as will insure the satisfactory completion of the work, the Supervisors shall then have the right to order the Contractor to cease all work. The Contractor shall immediately respect such notice, stop all work, and cease to have any right on the ground. The Supervisors shall then take such means as may be necessary to complete the work. If the cost shall then be greater than the contract price, the Contractor shall pay such difference to the Supervisors, and his bond shall be security for his payment.

3. Contractor's Liability.—The Contractor shall be liable for all accidents and damages that may accrue to persons or property during the prosecution of the work, by reason of negligence or carelessness of himself, his agents, or his employees. The work shall be conducted in conformity with all state or municipal laws and ordinances applying to the work, and precautions shall be taken to guard against accidents and loss of life.

Before beginning work, the Contractor shall furnish the Supervisors with satisfactory evidence that he will be able to discharge all obligations resulting on the work, through the operation of Sections 102.01 to 102.34 of the Wisconsin Statutes through authorized liability insurance, or that he has been exempted as provided in Section 102.28.

4. Instructions to Foreman.—The foreman, or other person in charge of any particular portion of the work, shall receive and obey the instructions of the Engineer, relating to that particular part of the work, in case the Contractor is not present. Any foreman or workman employed by the Contractor on the work, who, in the opinion of the Engineer, does not perform his work in the proper manner, or who shall be disrespectful, intemperate, disorderly, or otherwise objectionable, shall at the written request of the Engineer, be forthwith discharged from the work.

5. Imperfect Work.—Any work or material which shall be imperfect, insufficient, or damaged by any cause whatsoever, shall, when pointed out by the Engineer or his authorized representative, be remedied immediately and made to conform with the plans and specifications. Any omission by the Engineer, or his authorized representative, to disapprove of, or reject, any such defective work or material, shall not be construed as an acceptance of the work, or as releasing the Contractor from remedying any defective work or material so as to conform to the plans and specifications.

6. Bond.—In order to guarantee the faithful performance of the contract, and the payment of all lawful claims for labor performed and material furnished in and about the work done thereunder, the Contractor shall, before beginning work, and not later than fifteen days after the acceptance of this proposal, file a good and sufficient bond with the party of the first part, in the amount of the contract. The said bond shall be in compliance with the provisions of Section 289.16 of the Statute.

7. Maintenance of Travel.—Unless the contrary is specified, such provision to maintain travel during construction, as may be deemed necessary shall be made by the party of the first part.

Where the road is required to be kept open to travel by the Contractor, the same shall be maintained in a safe condition and the Contractor shall be responsible under his bond for all accidents that may occur thereon due to the unsafe condition of the road. The Contractor shall be permitted to post such signs as may be approved by the Engineer warning the public of the probable increased danger due to construction. Until the work is accepted the Contractor shall take all necessary precautions and place proper guards for the prevention of accidents, and shall between sundown and sunrise maintain suitable and sufficient lights as warning signals.

Where the road is kept closed to travel, the Contractor shall erect and maintain a suitable barrier at each end of the work, and shall post such detour signs to direct the traveling public around the work as may be directed by the Engineer.

8. Changes.—The Supervisors shall have the right to make such changes in the plans and additions thereto as may be necessary or desirable, and such changes shall not invalidate the contract. All such changes shall be ordered in writing by the Supervisors, and approved by the Engineer. Should such changes be productive of increased cost to the Contractor, a fair and equitable sum, to be agreed upon in writing before such changed work shall have started, shall be added to the contract price, and in like manner deductions shall be made.

9. Inspector.—The Supervisors shall have the right, if they so desire, to maintain an inspector on the work, who shall have access to all its parts.

Inspectors shall be authorized to inspect all work done and materials furnished. Such inspection may extend to all or any part of the work and to the preparation or manufacture of the materials to be used. An inspector may be stationed on the bridge to report to the Engineer as to the progress of the work and the manner in which it is being performed. Also to report whenever it appears that the materials furnished and the work performed

by the Contractor fail to fulfill the requirements of the specifications and contract, and to call the attention of the Contractor to any such failure or other infringement. Such inspection, however, shall not relieve the Contractor from any obligation to perform all the work strictly in accordance with the requirements of the specifications. In case of any dispute arising between the Contractor and the inspector as to materials furnished or the manner of performing the work, the inspector shall have authority to reject materials or suspend the work until the question at issue can be referred to and decided by the Engineer.

The inspector shall perform such other duties as are assigned to him.

He shall not be authorized to revoke, alter, enlarge or release any requirements of these specifications, nor to approve or accept any portion of the work, nor to issue instructions contrary to the plans and specifications. The inspector shall, in no case, act as foreman or perform other duties for the Contractor, nor interfere with the management of the work by the latter. Any advice which the inspector may give the Contractor shall in nowise be construed as binding the Engineer in any way, or releasing the Contractor from fulfilling all the terms of the contract.

10. Definitions.—The terms "Contractor," "County," "Supervisors" and "Engineer" whenever used in connection with this contract shall be understood to have the meanings hereinafter stated.

Contractor.—The person or persons entering into this contract as party of the second part acting directly or through a duly authorized representative.

County.—The governmental unit or units entering into this contract, whether it be a County, City, Village or Town.

Supervisors.—The duly authorized representatives of the said governmental unit or units in this contract.

Engineer.—The State Highway Engineer of Wisconsin or his authorized representative.

11. Referee.—It is mutually agreed by both parties to this contract that the Engineer shall act as referee in all disputes arising under the terms of the contract, between the parties thereto, and his decision shall be final and binding on both alike.

12. Estimates.—When provided in the contract, the Supervisors shall make advances to the Contractor at the intervals named. The amounts shall be certified by the Engineer to the Supervisors, and shall equal the value of the work done less 15 per centum. The granting of any such estimates shall not be construed as total or partial acceptance of any part of the work.

13. Payment.—Upon the completion of the work, according to the contract, plans, specifications, and agreements as determined thereunder by the Engineer, the said Engineer shall make to the party of the first part a certified statement setting forth the work done by the Contractor, and the amount due him therefor. The obtaining of the certificate of the Engineer, as to the work done and the price therefor, shall be a Condition precedent to the right of the Contractor to be paid the sums due him under the terms of the contract. The Contractor shall pay all claims for work and labor performed and materials furnished in the execution of this contract provided in Section 289.16 of the Statutes.

CONCRETE IN FORMS

206. Work.—It is understood that the work to be done includes everything which might reasonably be considered necessary for a complete and workmanlike job in accordance with the plans and specifications in every detail. The contractor shall perform all excavation and place concrete of the class indicated on the plans, or ordered by the engineer, for culverts, abutments, wing walls, end walls, catch basins, bridges, and other structures as directed by the engineer. All concrete placed in the work shall conform to the requirements for concrete of the class specified. All concrete and other masonry shall be built to the dimensions and contours shown on plans, with all reinforcement shown thereon. The engineer shall have the right to order the removal of any masonry not so built. The excavations for foundations shall be according to the dimensions shown on plans and shall be carried to such depth as is necessary to secure good foundation free from all danger of damage from settlement, frost or scour even though necessary to exceed the depth shown, but there shall be no variation in depth without a written order as hereinafter provided. All excavated material and other obstructions to the stream bed at any point between the ends of the wings of the abutments shall be removed and the channel left clear and unobstructed. This includes the removal of any dirt in the banks of the stream necessary to give clear opening. Material suitable for back filling shall be placed in the fill back of the abutments. All foundation excavations in front of abutments and piers shall be refilled, all rubbish removed, and the bridge left in a neat condition.

207. Material.—Concrete shall consist of approved Portland cement, fine aggregate of sand, and coarse aggregate of broken stone or gravel, mixed in the proportions specified for the various classes given below.

On request samples of all these ingredients shall be submitted to and approved by the engineer.

208. Classification.—The proportions of concrete mixtures to be used in various parts of work shall be as specified on the detailed plans. The proportions shall be measured by volume, one sack of cement, weighing ninety-four (94) pounds net, to be considered one (1) cubic foot. In general, proportions shall be as follows:

Class A.—Unless otherwise specified, Class A concrete shall contain one and one-half ($1\frac{1}{2}$) barrels of cement per cubic yard of concrete. Proportions which will be satisfactory with well-graded aggregates are, approximately, one (1) part cement to two (2) parts fine aggregate to four (4) parts coarse aggregate.

The following shall be the standard tolerances for grading of coarse aggregate. For the sizes two (2) inch to one-fourth ($\frac{1}{4}$) inch, twenty-five per cent (25%) to seventy-five per cent (75%) of the total material shall pass a one (1) inch screen, not more than thirty per cent (30%) and not less than ten per cent (10%) of the total shall pass a one-half ($\frac{1}{2}$) inch screen, and not more than three per cent (3%) shall pass a one-fourth ($\frac{1}{4}$) inch screen. A tolerance of five per cent (5%) shall be allowed in the size of all screens.

Class B.—Unless otherwise specified, Class B concrete shall contain one and one-quarter ($1\frac{1}{4}$) barrels of cement per cubic yard of concrete. Proportions which will be satisfactory with well-graded aggregates are, approximately, one (1) part cement to two and one-half ($2\frac{1}{2}$) parts fine aggregate to five (5) parts coarse aggregate.

The following shall be the standard tolerances for grading of coarse aggregate. For the sizes three and one-half ($3\frac{1}{2}$) inch to one-fourth ($\frac{1}{4}$) inch, twenty-five per cent (25%) to seventy-five per cent (75%) of the total material shall pass a one and one-half ($1\frac{1}{2}$) inch screen, not more than twenty-five per cent (25%) and not less than ten per cent (10%) of the total shall pass a one (1) inch screen, and not more than three per cent (3%) shall pass a one-fourth ($\frac{1}{4}$) inch screen. A tolerance of five per cent (5%) shall be allowed in the size of all screens.

Class C.—Unless otherwise specified, Class C concrete shall contain one and five hundredths (1.05) barrels of cement per cubic yard of concrete. Proportions which will be satisfactory with well-graded aggregate are, approximately, one (1) part cement to three (3) parts fine aggregate to six (6) parts coarse aggregate.

The coarse aggregate shall be graded as stated under Class B.

Class D.—Unless otherwise specified, Class D concrete shall contain one and six-tenths (1.6) barrels of cement per cubic yard of concrete. Proportions which will be satisfactory with well-graded aggregates are, approximately, one (1) part cement to two (2) parts fine aggregate to three and one-half ($3\frac{1}{2}$) parts coarse aggregate.

The following shall be the standard tolerance for grading of coarse aggregate. For the sizes one (1) inch to one-fourth ($\frac{1}{4}$) inch, twenty-five per cent (25%) to seventy-five per cent (75%) of the total material shall pass a one-half ($\frac{1}{2}$) inch screen, and not more than three per cent (3%) shall pass a one-fourth ($\frac{1}{4}$) inch screen. A tolerance of five per cent (5%) shall be allowed in the size of all screens.

By order of the engineer, the proportions of fine and coarse aggregate specified in the above classification may be varied slightly in order that a dense concrete with the specified content of cement may be obtained. If the engineer shall order, in writing, proportions differing in cement content from those specified, any suitable change thus necessitated and agreed upon in advance shall be made in the contract price.

If the contractor shall use cement in excess of one hundred five (105) per cent of the specified amount in any day's run, he shall receive no pay for the excess cement, if the contractor is furnishing cement, and if the state is furnishing it, the cost of the extra cement shall be deducted from the contractor's estimates.

It is further specified that the price bid per cubic yard of concrete is to exclude the cost of the cement, and that a separate and distinct bid is required on the cost per barrel of cement in place in the work. The contractor, when the State does not furnish cement, in making his bid on cement, shall state, in addition to his price per barrel in place, the price per barrel of cement, f. o. b. destination which he used in figuring his bid, said price to be

exclusive of discounts. He shall also name the destination. In case the price per barrel of cement at said destination is more or less than the price used in the bid, due to changed price at the mill or changed railway freights, the said increase or decrease in price shall be added to or subtracted from the price bid on cement.[1]

If cement is furnished to the contractor by the Commission, said contractor is not to include the price of cement (stated in the proposal) in his bid. In other words, he is to name a price per barrel for handling the cement only.

209. Portland Cement.—All Portland cement used shall meet the requirements of the standard specifications and tests for Portland cement adopted by the American Society for Testing Materials, and known as Serial Designation C 9–21, together with all subsequent amendments thereto, and also an additional specification that when the cement is mixed in the proportion of one part cement to three parts standard Ottawa sand by weight, and cured one day in moist air, and two days in water, the average tensile strength of not less than three of these briquettes shall be equal to or higher than 150 pounds per square inch. The average tensile strength of standard mortar at seven days shall be higher than the strength at three days.

All cement shall be properly protected against dampness and no cement shall be used which has become caked. Before the contractor shall be entitled to payment for the work, he shall present satisfactory evidence to the engineer that the full amount of cement required by the proportions specified for the work has been used.

210. Fine Aggregate.—Fine aggregate shall consist of natural sand or screenings from hard, tough, durable crushed rock or gravel, composed preferably, of quartz grains, graded from fine to coarse, with the coarse particles predominating. Fine aggregate when dry shall pass a one-quarter ($\frac{1}{4}$) inch round opening; between twenty-five (25) and seventy-five (75) per cent shall pass a sieve, having twenty (20) meshes per linear inch; not more than twenty-five (25) per cent shall pass a sieve having fifty (50) meshes per linear inch; and not more than five (5) per cent shall pass a sieve having one hundred (100) meshes per linear inch. Fine aggregate shall not contain organic or other deleterious matter, not more than three (3) per cent, by weight, of silt. Routine field tests may be made on the fine aggregate as delivered. In case the laboratory test shows that it contains more than three per cent (3 %) silt by weight, the entire lot of fine aggregate represented by the sample shall be rejected.

The percentage of silt, by volume, in the sand, may be determined from the colorimetric test, or, more accurately, in the following manner: Select two glass bottles, jars, or graduates which have uniform bore over a depth of eight (8) inches or more. The minimum diameter should not be less than one and one-half ($1\frac{1}{2}$) inches. Select two representative samples of the material under test, each sufficient to fill a vessel to a depth of two and one-half ($2\frac{1}{2}$) inches. Add enough water to make the total depth of the mixture of sand

[1] The twelfth paragraph under Clause 208 of "Concrete in Forms" shall not apply to bridge contracts. All bids for bridge work shall be a lump sum proposal as set forth in "Instructions to Bidders."

and water five (5) inches after shaking. Cover the top with hand or cork and shake vigorously for at least thirty (30) seconds. Hold the vessel in upright position, and tap its side with the finger to level the top of the sand. Allow to stand for one (1) hour. Then read the depth of silt to the nearest one-hundredth ($^1/_{100}$) inch, and measure the total depth of sand and silt, making four measurements at different points around the container. By dividing the depth of the silt by the total depth of sand and silt, and multiplying by 100, the percentage of silt by volume is found. If the average percentage of silt in the two bottles exceeds six (6), make a second determination of the percentage of silt after the vessel and contents have stood for six (6) hours. In case the average result obtained after the sample has stood six (6) hours is still above six (6) per cent, the engineer may reject or at his discretion send a twenty (20) pound sample of the material to the laboratory for test.

The presence of organic matter in the fine aggregate may be detected by the colorimetric test, which may be made as follows: Fill a graduated, wide-mouthed nursing bottle to the four and one-half ($4^1/_2$) ounce mark with the sand under test. Add a three (3) per cent solution of sodium hydroxide, until the level of the liquid reaches the seven (7) ounce mark after the mixture has been shaken. After thorough shaking, allow the mixture to stand eighteen (18) to twenty-four (24) hours, and observe the color of the clear, supernatant liquid. If clear or of light straw color, the sand is free from harmful proportions of organic impurities. If the color of the liquid is dark amber to black, the sand shall not be used before it has been subjected to the standard mortar strength tests.

Fine aggregate shall be of such quality that a mixture composed of one (1) part Portland cement and three (3) parts of fine aggregate by weight when made into briquettes shall show an average tensile strength at seven (7) and twenty-eight (28) days equal to or greater than the average tensile strength of briquettes composed of one (1) part of the same cement and three (3) parts standard Ottawa sand by weight.

The percentage of water used in making briquettes of cement and fine-aggregate shall be such as to produce a mixture of the same consistency as that of Ottawa sand briquettes of standard consistency. The word "sand," if used on plans or elsewhere, in specifying concrete proportions, shall be understood to be the fine aggregate as herein defined.

The right is reserved by the State to forbid the use of fine aggregate from any plant when the character of the material in such plant, or the mode of operation in such plant is such as to make improbable the furnishing of reasonably uniform fine aggregate, free from clay, silt or loam.

211. Coarse Aggregate.—Coarse aggregate shall consist of clean, hard, tough, durable crushed rock or pebbles, having reasonably uniform gradation of material passing a screen having two (2) inch openings and retained on a screen having one-quarter (¼) inch round openings.

When the material is tested with laboratory screens it shall meet the following requirements:

Retained on a 2-inch (round openings) screen.......	0.00%
Retained on a 1-inch (round openings) screen.......	30 to 70%
Retained on a ½-inch (round openings) screen.......	70 to 85%
Retained on a ¼-inch (round openings) screen.......	100.0%

A tolerance of five (5) per cent shall be allowed for wear in size of openings of all screens.

Unless approved by the Engineer, no broken stone aggregate shall be used which has a French coefficient of wear less than six (6).

The right is reserved to reject for cause any and all stone or gravel delivered on the work.

Coarse aggregate consisting of crushed stone shall be of uniform character quarried from strata of approximately equal hardness, and the right is reserved by the State to forbid the use of crushed stone aggregates from any quarry when the character of the stone in the breast being operated and the mode of operation in blasting and handling is such as to make improbable the furnishing of uniform and graded crushed stone aggregate free from clay, silt or loam.

The word "stone," if used on plans or elsewhere in specifying concrete proportions shall be understood to be coarse aggregate as herein defined.

The right is reserved by the State to forbid the use of gravel pebble aggregate from any plant where the character of the material in such plant, or the mode of operation in such plant, is such as to make improbable the furnishing of hard and reasonably uniform well graded pebble aggregate, free from clay, silt or loam.

212. Water.—All water used in concrete shall be subject to the approval of the engineer and shall be reasonably clear, free from oil, acid, alkali or vegetable substances and shall be neither brackish nor salty.

213. Mixing.—The concrete shall be mixed in the quantities required for immediate use and any which has developed initial set, or which does not reach the forms within thirty (30) minutes after the water has been added shall not be used.

Unless hand mixing is specially permitted by the engineer, the mixing shall be done in a batch mixer of approved type which will insure the uniform distribution of the materials throughout the mass so that the mixture is uniform in color and smooth in appearance. The mixing shall continue for a minimum time of one (1) minute after all the materials are assembled in the drum, during which time the drum shall revolve at the speed for which it was designed, but shall make not less than fourteen (14) nor more than twenty (20) revolutions per minute.

Where a fraction of a sack of cement is used the method of weighing or measuring shall be approved by the engineer.

214. Hand Mixing.—When hand mixing is permitted it shall be done on a watertight platform. The fine aggregate and cement shall first be mixed until a uniform color is attained and then spread over the mixing board in a thin layer.

The coarse aggregate which shall have been previously drenched, shall then be spread over the fine aggregate and cement in a uniform layer and the whole mass turned after the water is added. After the water has been added the mass shall be turned at least four (4) times and more if necessary to make the mix uniform in color and smooth in appearance. Hand mixed batches shall not exceed one-half (½) cubic yard in volume.

215. Retempering.—All mortar and concrete shall be used while fresh before the initial set has begun. No retempering of mortar or concrete shall be allowed.

216. Consistency.—The consistency of the mix of the concrete shall be such that the mortar clings to the coarse aggregate. It shall not be sufficiently soft to flow rapidly or segregate. When the concrete is allowed to drop directly from the discharge chute of the mixer, the center of the pile of concrete shall flatten, but the edges shall stand up and not flow. The water shall be accurately measured and gauged and shall be automatically discharged into the drum with the aggregates. Quantity of water to be used shall be determined by the engineer and shall not be varied without his consent.

217. Depositing Concrete.—Concrete shall be so deposited that the aggregates are not separated. Dropping the concrete any considerable distance, depositing large quantities at any point and running or working it along forms, or any other practice tending to cause separation of the aggregates will not be allowed.

Throughout the placing of the concrete in the forms, the mass shall be puddled or spaded sufficiently to insure perfect contact and bond with the reinforcing bars, and perfect contact with the surfaces of the forms. Smooth, finished surfaces shall be obtained by working the finer materials against the forms. Faces which show in the finished work shall be true to form intended and shall be wholly free from swells, ridges, holes, cavities, mortar shortages and so forth.

Wherever practicable, concrete shall be deposited continuously for each monolithic section of the work. All floors and other thin work shall be placed full thickness.

All slab and deck girder spans shall be placed complete to the top of the wheelguard in a single operation as outlined below, and the contractor shall, before beginning this part of the work, have sufficient material of all classes on the ground, adequate equipment, and the necessary labor force available to finish the work. On through girder and slab spans the forms for the railing shall be assembled sufficiently so that they can be set in place without delay. Concrete in the railings shall be poured the day after the concrete in the floor has been placed.

Slab spans shall be placed in longitudinal strips. Concrete shall first be placed in the middle of the span and carried in both directions full height uniformly towards the ends of the span. Pouring shall commence at the curb and continue across the roadway. The width of strips shall be such that the concrete in any one strip shall not take its initial set before the strip adjacent is poured. In case the mixer is disabled, a vertical joint shall be

made parallel to the center line of roadway and enough concrete shall be mixed by hand to complete the strip.

Deck girder spans shall be placed in longitudinal sections. Concrete shall first be placed in the middle of the span and carried in both directions full height uniformly towards the end of the span. Pouring shall commence at one curb and continue across the roadway. The width of sections shall extend between points midway between girders. In case the mixer is disabled, a vertical joint shall be made parallel to the center line of roadway and enough concrete shall be mixed by hand to complete the section. This joint is to be placed at the edge of one of the sections. To prevent a honeycombed bottom surface of the girders and before any concrete is deposited, not less than a three (3) sack batch of 1:2 cement grout shall be placed in the center of the girder.

Concrete in walls shall be placed in continuous horizontal layers extending from end to end of the wall. Whenever Stops are made, the top surface shall be leveled off in a horizontal plane and grooved in the center with a 4″ × 4″ timber whose top face is flush with the concrete surface. The 4″ × 4″ timber shall be removed as soon as the concrete has taken its initial set. When new concrete is placed on concrete which has a complete or partial set, the surface shall be thoroughly cleaned and scraped to remove all rubbish, badly cured concrete, laitance or other material detrimental to the finished work. The old surface shall then receive a coat of neat cement paste applied immediately in advance of the first batch.

Bridge floors shall be built true to the dimensions shown on the plans, and the curbs shall be cast in the same operation as the balance of the floor. The curb forms shall be built to correct alignment and the contour of the top of the floor shall be determined by a strike board cut accurately so that the finished floor will conform to the dimensions shown on the plans. The top surface shall be floated to an even surface. Curbs shall be finished with a metal trowel and brushed. Corners shall be rounded with an edging tool. Face of curbs shall be bricked. Sidewalks shall be metal trowled and brushed.

Arch rings shall preferably be placed entire or, where this is not practicable, in monolithic rings with vertical joints parallel with the center line of the roadway, and each day's work shall finish with one of these rings complete. Special care shall be observed to obtain good connection of spandrel walls to arch rings.

Whenever concrete is desposited in freezing weather, special precautions shall be taken to avoid the use of materials containing frost, and thoroughly effective means shall be used to prevent the wet mixture from chilling or freezing. The water should be boiling and the aggregate heated to a temperature of not less than one hundred fifty (150) degrees Fahrenheit before the ingredients are placed in the mixer. The concrete shall be placed in the forms immediately after mixing.

The entire work shall be covered in such a way as to retain the heat and prevent freezing of concrete in the wall. The use of salt to prevent freezing

shall not be allowed, and all concrete placed in freezing weather shall be at the contractor's risk.

Concrete may be deposited through water only by special authority from engineer, and that in writing. When so deposited it shall be by means of one or more tremies or chutes. The lower ends shall be placed on the bottom of the foundation and the tremie kept filled, concrete escaping from the bottom because of a slight raising of the tremie. The surface of the concrete shall be kept level, and the work having once been started, shall be carried on continuously until that portion of the foundation to be deposited in water is completed. When the work is continued, the water shall be exhausted and the surface cleaned as hereinbefore described. The contractor shall have sufficient material on hand and labor available to guarantee that this can be done. The tremie shall be charged in such a way that the cement is not washed out of the concrete, and whenever the charge is lost, it shall be recharged in the same manner before placing is continued. In all cases where concrete is deposited through water, as hereinbefore described, the same shall be a Class A mixture. No concrete shall be poured unless an inspector is present.

218. Forms.—All forms shall be built tight and substantial, so as to retain the finer parts of the concrete mixture, and to hold rigidly to place until the concrete has set. Forms which have sagged, bulged, or become warped or distorted in any way shall immediately be removed and the concrete affected thereby replaced with fresh concrete. The engineer shall have the right to require forms to be held in place by means of rods and waling strips.

All lumber used for surface forms shall be of an even surface. Where the concrete will be exposed to view, the forms must be built of selected lumber, sized and dressed, and free from defects which will show in the finished work. All joints shall be neatly fitted; triangular chamfer strips shall be carefully fitted with mitred corners.

The forms for all concrete girders, railings, and arch spandrels shall be built with especial care from selected lumber, which shall have been carefully cut, planed and fitted in a planing mill, in such a way that the finished concrete work shall be of the exact dimensions shown on the plans. These forms shall be set up entire, firmly braced and inspected by the engineer before any concrete is placed in this part of the work.

In framing centering for arches, allowance shall be made for settlement of centering, deflection of the arch after removal of centering and permanent camber. Centers shall be framed for a rise of arch $^3/_{16}$ of an inch for each 10 feet in span greater than the rise marked on the drawings. The centers shall be so designed as to be rigid in place and free from all sagging and bulging. No concrete shall be poured until the engineer has inspected the centering and passed on its sufficiency.

Effective means shall be used to prevent the adhesion of the concrete to the forms. The inside surfaces of all forms for girders, railings, or arch spandrels, or any other ornamental work, shall be well covered with shellac or a light oil one day before the concrete is placed.

Before concrete is placed, the forms shall be thoroughly wet and cleaned of all accumulations of rubbish. Care shall be observed to insure that the forms are cleaned in advance of pouring, from all dirt, or concrete which may have spattered and dried on the inside of the forms.

In structures six (6) feet in span and under, the year of construction is to be stamped into the concrete on one end face of one wing wall or end wall in such a position as to be readily accessible for inspection.

219. Removal of Forms.—In order to make possible the obtaining of a satisfactory surface finish, forms, on ornamental work, railings, parapets, and vertical surfaces that do not carry loads and which will be exposed in the finished work shall be removed in not less than four (4) nor more than forty-eight (48) hours, depending upon weather conditions. Forms under slabs, beams, girders, and arches shall remain in place at least twenty-one (21) days in warm weather, and in cold weather at the discretion of the engineer. Forms shall always be removed from columns before removing shoring from beneath beams and girders, in order to determine the conditions of column concrete.

The removal of forms before the concrete has sufficiently set shall not relieve the contractor of responsibility for the safety of the work. As soon as the forms are removed all rough places, holes, and porous spots shall be filled, and all bolts, wires, or other appliances used to hold the forms and which pass through the concrete shall be cut off or pushed back with nail set one-half ($\frac{1}{2}$) inch below the surface and the ends covered with cement mortar of the same mix as used in the body of the work.

As soon as the forms are removed from the base rail, coping or other ornamental work, the construction joints shall be opened and the edges beveled back sufficiently to prevent breakage at the junction points; the concrete shall be beveled back not to exceed an eighth of an inch both sides of all expansion joints in ornamental work.

On spans carrying baluster railing, the centering shall be removed before the top rail of the railing is placed.

220. Surface Finishing.—The contractor shall build the forms, and place the concrete, in such a way that a smooth, even surface will be presented on removal of the forms, and the work of finishing thereby reduced to a minimum.

All concrete surfaces shall be well spaded by forcing a flat blade spade vertically down between the concrete and the form, and then by pulling the top of the spade away from the form so that the mortar will in all cases flow to the face of the forms.

The rubbed finish shall be made by carefully rubbing the surface with a fine carborundum brick, immediately after removing the forms. The first step in this process is to moisten the surface with water, immediately following with the fine carborundum brick, rubbing in a circular motion. Only light pressure should be applied and the rubbing continued until all the air holes and small depressions are filled, and an excess of mulch is on the surface. The mulch should then be brushed out smooth with a long bristle paint brush.

After the concrete has been rubbed smooth and has set for a period of from five (5) to eight (8) days, it shall then be again rubbed, using a carborundum brick. Rubbing shall be continued until a smooth surface free from lumber marks and irregularities is obtained. In using carborundum brick, the surface to be rubbed may be moistened with water to facilitate the rubbing; the fine material loosened by the brick may be used to fill the pores in the concrete. On warm days when the sun is quite strong, rubbed surfaces should be covered with canvas to keep the sun from drying out the surface too rapidly, thus causing checking.

Before final acceptance all dust left on finished surfaces by the action of brick shall be removed by rubbing with canvas, when the surface is perfectly dry.

221. Concrete Balusters.—The concrete in concrete balusters shall consist of a mixture of one part of cement, one-half of which is white cement, and two parts fine aggregate.

The fine aggregate shall conform to the specifications for fine aggregate in concrete pavements.

The aggregate shall first be very thoroughly mixed in a dry state by shoveling on a tight board for not less than ten (10) minutes. The water shall then be added to produce a concrete of the consistency specified elsewhere in these specifications. After placing in the forms, the concrete shall be tamped with unusual care in order to insure that no voids remain and that the air pockets on the surface of the balusters are reduced to a minimum.

After brushing, the balusters shall be carefully stored, sheltered from rain, sun or other damage, and cured under a damp canvas for a period of at least six (6) days.

At the time the concrete baluster has reached the proper degree of set (approximately ten (10) days after pouring) it shall be carefully rubbed to a smooth, even finish with a fine-grained carborundum brick.

All balusters shall be manufactured by skillful, experienced workmen, and no imperfect cracked or damaged balusters will be accepted.

222. Curing Concrete.—Careful attention shall be given by the contractor to the proper curing of the concrete. Handrails, floors and troweled surfaces shall be protected from the sun, and in drying weather the whole structure shall be kept wet for a period of one (1) week. Concrete floor slabs may be covered with damp sand as soon as the concrete has taken its initial set and then kept wet for one (1) week. Other precautions to insure thorough curing of the concrete shall be taken by the contractor as directed by the engineer. The roadway shall be kept closed to traffic for three (3) weeks or if in the opinion of the engineer the weather conditions make it advisable, the roadway may be opened to traffic in a shorter or longer period of time, provided the closed period shall never be less than two (2) weeks after the concrete is deposited.

223. Foundation for Concrete.—Where concrete is to rest on any excavated surface other than rock, special care shall be taken not to disturb the bottom of the excavation, and the final removal of material to grade shall not

be made until just before the concrete is laid, except in concrete foundations for pavement.

The excavation lines and bases of structures shown on the plans shall be considered only as approximate and they may be ordered in writing by the engineer to be placed at any elevation or of any dimension that will give a satisfactory foundation. Any additional concrete that may be required by the engineer below or beyond the line shown on the plans shall be paid for at the contract price. No structure shall be commenced without the engineer's approval. All rock or hard pan foundation surfaces shall be freed from loose pieces, cut to firm surfaces, and cleaned to the satisfaction of the engineer before laying concrete. All seams shall be cleaned out and filled with concrete or mortar, and payment for such concrete used in filling shall be made at the contract price for the class of concrete used.

224. Measurement and Payment.—The quantity of concrete to be paid for shall be the number of cubic yards under the various classes measured in place in the finished structure placed in accordance with the plans, or as ordered by the engineer. No payment will be made for any concrete outside of these limits nor for any concrete whose replacing is rendered necessary owing to lack of proper care, and the price paid per cubic yard shall include all materials, forms, labor and other incidental expenses necessary to satisfactorily complete the work as specified in the foregoing paragraph. Unless otherwise stipulated all excavation required for placing concrete shall be included in the price bid for concrete.

Exercise.—If a reinforced concrete slab bridge was to be built of Class *A* concrete in Wisconsin during July and August, what clauses in the detailed specifications for Concrete in Forms would not be needed?

JOB 37. PLANS

Plans and drawings are used as a part of a complete contract to help the parties to visualize correctly the structures. Many details that are very difficult to describe with words are easily shown by means of drawings.

In general, the complete plans for a concrete building may show the location of the lot, including its dimensions and boundaries and sometimes contours; basement, floor, and roof plans; elevations; framing plans; sections; and details. In addition to these, there may be plans for plant layout, forms and framing, reinforcement bending, various details, etc., according to the judgment of the engineer or architect and the needs of the contractor. Plans for a concrete arch bridge would include the site, plans, elevations, stress sheet, sections, and details.

The scales used for plans vary greatly, depending on the job in particular, and the opinion of the engineer or architect. Scales

of 1/4 or 1/8 in. to the foot are common for general plans, and 3/4 or 1½ in. to the foot for details.

When obtaining dimensions from plans, the distances given in figures will usually take precedence over the scaled distances. Tracing cloth, drawing paper, and blueprint paper often shrink a little with age, so that drawings which scale correctly when they are made will not scale correctly a few months later.

In most drawings, various symbols are used to take the place of words. The selection and use of symbols vary somewhat in different localities, in different offices, and with different trades. Some of the common symbols used in concrete work are:

6″	means 6 in.	3′	means 3 ft.
4□″	means 4 sq. in.	2′□′	means 2 sq. ft.
½″φ	means ½-in. round rods	℄	means center line.
¾″▯	means ¾-in. square rods		

3″ o.c. or 3″c.c., means that rods are spaced 3 in. on centers or from center to center.

Common abbreviations for words such as lb. for pounds; in. for inches; ft. for feet; M for thousand; squares for 100 sq. ft.; sq. ft. for square feet; cu. ft. for cubic feet; sq. yd. for square yard; cu. yd. for cubic yards; bd. ft. for board feet; etc., are also used in concrete work.

When reading plans and blueprints, information for some particular item is usually wanted in regard to its location, dimensions, kind, finish, or quantity. Reading of plans and blueprints is not very difficult, but it does require careful attention to detail, especially upon the part of a beginner. Anyone who has completed a drafting course in school, or who has had some experience in a drafting office, should have no difficulty in reading and understanding the average structural drawings. Drawings that are incomplete, inaccurate, or otherwise poorly drawn will cause trouble for any plan reader, quantity surveyor, estimator, or constructor. Plan reading is simply the examination of the drawing or blueprint, to secure some information that is shown in the drawings or blueprints.

In the following job, there are complete plans for a reinforced-concrete slab highway bridge. An examination of these drawings will bring out much information in regard to plans for concrete work, especially if the questions in the following job are carefully

answered. In a later job, a quantity estimate has been prepared for this particular concrete structure. Checking this quantity estimate against the plans and specifications will give the average student a good understanding of what is meant by plan and blueprint reading.

Exercises.—What are plans or drawings?

What is the object of making drawings for a concrete structure?

Name the drawings which, in your opinion, should be provided for a one-story concrete garage with basement.

What scales would you use in preparing the general and detailed drawings for this garage?

What is plan reading?

JOB 38. STANDARD PLANS FOR A REINFORCED CONCRETE HIGHWAY BRIDGE

The plans shown in Fig. 71 are standard plans for a reinforced concrete slab highway bridge, with a clear span of 16 ft. and a 28-ft. roadway. These plans contain a half-side elevation, a half section just inside a rail, a half-end elevation, and a half section through the paneling at the center of the span, as well as a bill of reinforcing steel, a detail of the drain, general notes, and estimated quantities.

In Fig. 72, are shown the horizontal plan, front elevation, end view of a wing, and sections of a reinforced concrete abutment suitable for the slab bridge shown in Fig. 71. Note that several dimensions are omitted in the abutment plans. These dimensions are to be filled in when the height of the abutments, width of roadway, clear span, and depth of the reinforced concrete slab bridge have been determined for the particular job in question.

Exercises.—Using the bill of bars, check the total weight of reinforcing steel required in the plans for the reinforced concrete slab bridge shown in Fig. 71.

What would be the required width of the bridge seat in the abutment plans of Fig. 72 to care for the slab bridge of Fig. 71.

What would be the required depth of the bridge seat notch?

JOB 39. PLAN READING

Plan reading is simply examining the plans to secure some desired detailed information. Any person who can read English fairly well, and who will pay careful attention to details, should not have much difficulty in learning to read plans.

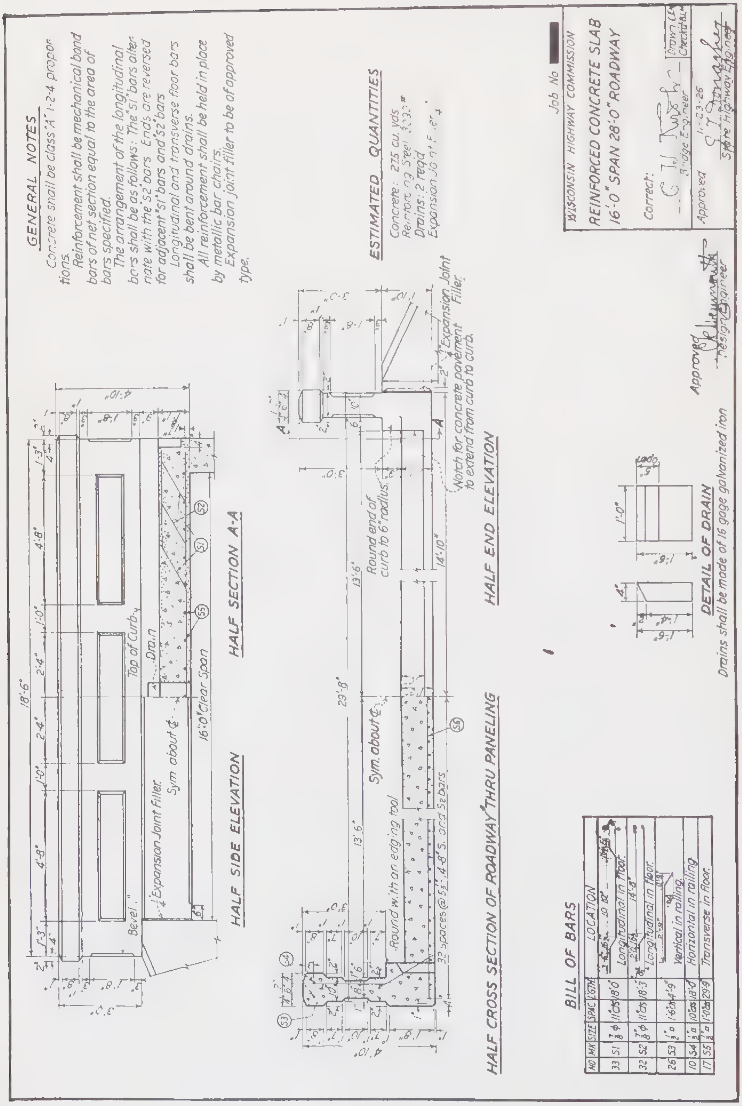


FIG. 71.—Plans for a reinforced concrete slab of sixteen-foot span and twenty-eight foot roadway.

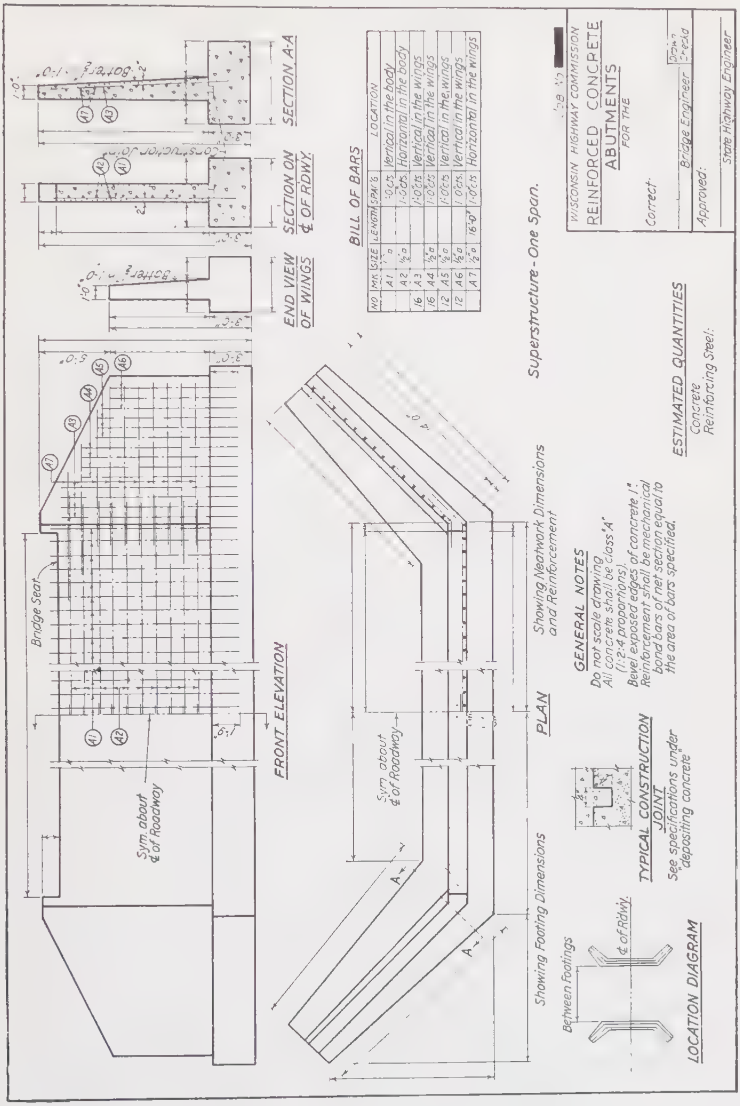


FIG. 72.—Plans for reinforced concrete slab-span abutments.

The following questions and answers in regard to the reinforced concrete slab bridge, shown in Fig. 71, will illustrate to some extent what is meant by plan reading.

Question: What is the depth of the slab at the center of the roadway?

Answer: From the half-end elevation, the depth is shown to be 1 ft. 2 in.

Question: What is the depth of the slab near the rail?

Answer: From the half-end elevation or the half section *A-A*, the depth is shown to be 1 ft. 1 in.

Question: How far above the bottom of the slab is the main tensile reinforcement (7/8-in. round bars) placed?

Answer: From half section *A-A*, the centers of the 7/8-in. round bars are to be 1 7/8 in. above the bottom of the slab.

Question: What is the total length of the slab?

Answer: From the half-side elevation and the half section *A-A*, the total length of the slab is 18 ft. 6 in.

Question: What is the total overall length of the bridge?

Answer: From the half-side elevation and the half section *A-A*, the total overall length of the bridge is 18 ft. 6 in. plus 4 in., or 18 ft. 10 in. The ends of the rail extend 2 in. beyond each end of the slab.

Exercises.—Where are the drains placed?

How many drains are required?

How many main reinforcement bars (7/8-in. round bars) are required?

What is the total width of the top part of the bridge rail?

How high is the bridge rail above the curb?

How high is the curb?

How wide is the curb?

Are there any sidewalks provided on this bridge?

Where are the expansion joints located?

What are the dimensions of the recessed panels in the bridge rail?

How many of these recessed panels are there?

What is the spacing of the main reinforcement bars (7/8-in. round bars) in the floor slab?

What is the total number of bends to be made in these 7/8-in. round bars in the floor slab?

What is the spacing of the transverse reinforcement (1/2-in. square bars) in the floor slab?

How far from the center of the slab are each of the three bends of the 7/8-in. round bars made? (See half section *A-A*.)

What are the dimensions of the notch left in each end of the bridge floor slab for the concrete pavement?

What kind of reinforcement bars are required? (Plain or deformed?)

What kind or class of concrete is required?

What is the "crown" in inches provided in the center of the bridge floor slab?

What is the total overall width of the bridge?

SECTION IV

ESTIMATING

JOB 40. ESTIMATING IN GENERAL

The work of estimating is commonly divided into two parts: (1) estimating quantities or "taking off," and (2) estimating unit costs.

A simple concrete job may be divided into the following parts in regard to quantities and units:

1. Excavation in cubic yards.
2. Forms and false work in square feet of form surface.
3. Concrete in cubic yards.
4. Steel in pounds or tons.
5. Finishing in square yards.
6. Cleaning up for job.

For a more complicated job, such as a reinforced concrete building, other items should be added, as masonry (brick, stone, terra cotta) in cubic feet or per thousand brick or block; lath and plastering in square yards; building trim, windows, and doors: hardware; iron work; roofing in squares of 100 sq. ft. or sq. yd.; flashing; painting in square yards; sundries; subcontracts; and general overhead (if not previously apportioned).

Each of these divisions may be subdivided into the following parts:

a. Material in units suitable for each kind of material.
b. Labor in hours.
c. Plant in hours or days.
d. Overhead in hours.

Sometimes an estimator will use the subdivisions *a*, *b*, *c*, and *d* as the main divisions and then use the divisions 1, 2, 3, 4, etc.; as subdivisions.

A complete estimate of the quantities of materials may be said to be a "quantity survey. In some localities the "quantity surveyor" prepares a list of materials for any given job and all

contractors, who bid on the job, use this list. The contractors make their own individual estimates for labor, plant, and overhead.

The preparation of a list of materials is known as the "take off." The estimator tabulates all of the different materials as to kind, number, size, weight, volume, or other units used. The selection of units for different materials will be explained in more detail in later jobs.

In estimating the quantity of labor for a given job, the total number of labor hours or man hours for each class of labor and each kind of work is tabulated. It is often difficult to estimate accurately the number of hours required for a laborer to perform a given task, as some laborers work faster or slower than the average. When a contractor has had practically the same gang working for him for a few months, his experience will enable him to estimate quite closely as to the amount of work this particular gang will do in a day or an hour.

The selection of the plant will often depend on the machinery that the contractor has available for the job. The estimate of the time that the plant will be used may be based on the total time that the plant is held available for the job, or on the total time that the plant is run, or on both.

The estimate of overhead may be given in hours or days that will be required of the superintendent, engineers, inspectors, clerks, stenographers, watchmen, etc., to care for the work of this particular job.

When estimating unit costs, the costs of the materials at the job are usually computed. This cost includes first cost, freight, unloading, cartage, storage, inspection, testing, and insurance.

Total labor costs are found by multiplying the hours estimated for each class of labor by the corresponding wage rate per hour, and then adding results.

Plant costs usually include cost of installation, maintenance, operation, removal, interest on investment, and depreciation (proportionate part of first cost of plant). These costs often include the labor costs of machine operators, such as hoisting engineers, firemen, etc. To get unit costs, the total cost of the plant on the job is computed and divided, either by the total number of hours that the plant is held available for the job, or

else by the number of hours that the plant is actually operated on the job. Some estimators use two plant hour rates; one when the plant is idle, and another when the plant is running.

Overhead costs include such general office and other labor costs that are not considered as direct productive labor on the job. Other overhead costs are insurance, rents, office stationery, expense of plans and specifications, interest, legal expenses, traveling expenses, sundries, etc. These overhead expenses are often apportioned to the several parts of the job according to the labor hours or labor costs of these parts, though sometimes some of the overhead costs are assigned to the materials and plant.

Last, but not least in importance, is the profit. The amount of profit is usually expressed as a percentage of the total cost of the job. This percentage usually varies from about 8 to 15 per cent, depending on the contractor's desire for the work, what he thinks is fair, and what he thinks he can get. For small jobs, 15 per cent is a common figure for profit with $12\frac{1}{2}$ per cent for medium jobs, 10 per cent for large jobs, and possibly 8 per cent for very large jobs. The percentage of profit added also depends, to some extent, on how often payments are to be made and in what amounts. On large jobs, payments up to about 85 per cent of the total work done are made each month.

Exercises.—Name the six main divisions of concrete work.
Name the four subdivisions.
What is a "quantity survey" and how is it made? What is a "take off?"
What things are usually included in material costs?
What is meant by overhead and what does it include?

JOB 41. ESTIMATING EXCAVATION

While it is comparatively easy to compute the quantities for excavation, there are several items which will affect the total labor required and the costs.

Excavation is usually divided into two classes: (1) general excavation, such as excavating for a large cellar or making a cut for a railroad or a highway; and (2) particular or special excavation, such as digging narrow trenches, footing holes, etc. General excavation may be done by hand, scrapers and horses, or steam shovels, while hand work is practically always required for special excavation.

The time and cost of excavation also depends upon the character of the material to be removed. A cubic yard of hardpan may require from two to four times as much labor as a cubic yard of loam.

In computing quantities for excavation, the estimator must be careful to include the dimensions from outside to outside of footings, and from the top of the grade to the bottom of the basement floor.

In the "take off," each item of general and special excavation must be listed separately, with dimensions and quantities, as well as the kind of soil. Sometimes the earth will retain its vertical position without support. In other cases, the earth walls will require sheeting or bracing. In general excavation with steam shovels, it is sometimes more economical to omit the sheeting and slope the banks.

When computing quantities where the surface of the ground is sloping or uneven, the horizontal projection may be divided into a number of convenient squares and rectangles, and the average height of each section estimated.

The following table gives the angles of repose for various kinds of earth:

ANGLES OF REPOSE

Material	Angle with horizontal in degrees		
	Dry	Moist	Wet
Sand	20–35	30–45	20–40
Earth	20–45	25–45	25–30
Gravel	30–50		
Gravel, sand, and clay	20–35		

The work of excavation done per man per hour varies greatly with the skill of the laborer, his inclination to work, and the character of the soil. The following tables give approximate values:

Shoveling—Cubic Yards per Man per Hour Including Loosening with Picks and Shoveling into Wagons or Trucks

Total lift not more than 6 ft.

Material	General excavation		Special excavation
	Dry	Wet	
	Cubic yards per hour		
Sand and loam	0.60–1.60	0.50–1.00	0.30–0.70
Medium soil	0.40–1.00	0.25–0.50	0.20–0.40
Heavy soil and clay	0.30–0.60	0.20–0.40	0.15–0.35
Hardpan	0.25–0.50	0.15–0.35	0.10–0.30

Shoveling Loosened Material—Cubic Yards per Man per Hour When Shoveled into Wagons or Trucks

Total lift not over 4 ft.

Material	Cubic yards per hour
Sand and loam in excavation	0.90–1.75
Medium soil in excavation	0.85–1.65
Heavy soil and clay in excavation	0.60–1.30
Hardpan in excavation	0.50–1.20
Sand from ground to wagon	2.00–4.00
Stone and gravel from ground to wagon	1.50–3.50
Dirt from ground to wagon	1.50–4.00

A driver and helper with two horses and a plow can loosen from 15 to 40 cu. yd. of earth per hr. depending on the character of the soil. Heavy soil may require four horses.

Capacities of Vehicles

Ordinarily taken as 80 per cent of rated capacity

Vehicle	Cubic yards
Wheelbarrows	0.10–0.15
Drag scraper	0.10–0.25
Wheel scraper	0.35–0.65
Two-horse dump wagon	1.00–1.75
Auto trucks	1.00–5.00

ECONOMICAL HAUL (APPROXIMATE)

Vehicle	Distance
Wheelbarrows	Not over 100 ft.
Drag scrapers	Not over 150 ft.
Wheel scrapers	Not over 500 ft.
Dump wagons	500 ft. or over
Auto trucks	1000 ft. or over

TIME FOR HAULING

Vehicle	Load, minutes	Unload, minutes	Rate of travel, miles per hour
Wheelbarrow	1.00– 3.00	0.20	2
Drag scraper	0.25– 0.50	0.25	2
Wheel scraper	0.25– 0.50	0.25	2
Dump wagon	1.00– 9.00	0.25–1.00	2
Auto truck	1.00–12.00	0.25–1.00	8–15

Time required to load a wheelbarrow depends on whether one or two men are shoveling, and on the kind of material.

Time required for loading a dump wagon depends on number of shovelers in hand loading, on operation of shovel in machine loading, and on conditions of work.

GASOLINE OR STEAM SHOVEL CAPACITY

Size of shovel, cubic yards	Cubic yards per minute
3/4	1.00– 2.50
1 1/4	1.50– 4.00
1 1/2	2.00– 5.00
1 3/4	2.50– 6.00
2	3.00– 7.00
2 1/2	4.00– 9.00
3	5.00–11.00

The output of a steam shovel per minute depends on the amount of moving it must do, the time required to move the loaded truck and place an empty truck in position, the skill of the shovel operator, the speed of the shovel, and the character of the soil. Hence, all figures given above are approximate. Steam

shovels are often not economical when the amount of general excavation is less than about 1500 cu. yd.

Backfilling—Cubic Yards per Man per Hour When Material Is Shoveled into Trench and Tamped a Little

Material	Cubic yards per hour per man
Sand or loam	1.5 3.0
Medium soil	1.0–2.5
Heavy soil and clay	0.8–2.0

When the backfill material has to be wheeled, the amount of backfill per man per hour will be reduced proportionately.

Sheeting and bracing for trenches is usually estimated by the square foot of surface measurement of the earth retained. The amount of lumber in board feet for sheeting may vary from about 100 to 400 bd. ft. per 100 sq. ft. of surface measurement of retained earth. The cost of lumber for trench sheeting may vary from about \$35 to \$60 a thousand board feet. When the trench sheeting can be removed and used again, the wastage of lumber varies from about 20 to 50 per cent. One man will place from 7 to 10 sq. ft. of sheeting per hour and remove from 20 to 40 sq. ft. per hour depending on the depth of the trench.

The cost of labor per hour varies greatly in different localities and in different years, so that a knowledge of the local labor supply is essential in preparing a cost estimate. The following approximate values in preparing a cost estimate will be used:

Kind of labor	Wage or cost per hour, dollars
Unskilled	0.40–0.60
Skilled	0.80-1.40
Foreman	1.00-1.50
Man and team with scraper or wagon	1.00–1.50
Man and auto truck	2.00–5.00
Steam shovel with operator	2.50–7.50

Illustrative Problem.—Prepare an estimate of cost of excavation of 20,000 cu. yd. of general excavation, 400 cu. yd. of special excavation, 300 cu. yd. of backfill, and distance of haul of 1.5 miles. Assume medium

soil which will expand 20 per cent on excavation. Wage of unskilled labor is 50 cts. per hr., foreman $1 per hr., man and team and 2-cu. yd. dump wagon is $1 per hr., driver and 2½-cu. yd. auto truck is $3.50 per hr., operator and ¾-cu. yd. steam shovel is $4 per hr. Estimator has choice of dump wagons or auto trucks. Allow 15 per cent for overhead expenses and 10 per cent for profit. Compute total costs and cost per cubic yard.

Cost of General Excavation

Assume output of steam shovel to be 1.50 cu. yd. per min.

Cost of digging per cu. yd. $= \dfrac{\$4.00}{60 \times 1.50} = \$0.0444.$

Time of haul for 1 team and wagon = loading 1 min., unloading 0.50 min., time on road 90 min., totaling 91.50 min. per load.

Cost per load at $1 per hr. $= \dfrac{1.00 \times 91.50}{60} = \$1.525.$

Cost per cubic yard $= \$1.525 \div 1.5 = \$1.0167.$

Time of haul for auto truck = loading 1.33 min., unloading 0.50 min., time on road (assuming 8 miles per hr. loaded and 15 miles per hr. empty) 17.25 min., totaling 19.08 min. per load.

Cost per load at $3.50 per hr. $= \dfrac{3.50 \times 19.08}{60} \doteq \$1.113.$

Cost per cubic yard $= \$1.113 \div 2.0 = \$0.5565.$

Total time required for general excavation $= \dfrac{20{,}000}{1.50 \times 60} = 222.22$ hr.

Cost of foreman = $222.22.

Cost of foreman per cubic yard $= \dfrac{222.22}{20{,}000} = \$0.0111.$

Cost per cubic yard with trucks = $0.6120.

Use auto trucks.

Cost of 20,000 cu. yd. = $12,240 + $1836 overhead + 10 per cent of ($12,240 + $1836) profit = $15,484, or a cost of $0.774 per cu. yd.

Cost of Special Excavation and Backfill

For special excavation, assume labor output with shovel as 0.30 cu. yd. per hr.

Cost per cubic yard at $0.50 per hr. $= \dfrac{0.50}{0.30} = \$1.667$ per cu. yd., or $667 for the job.

Assuming eight men in shovel gang, time required will be $\dfrac{400}{8 \times 0.30} =$ 167 hr.

Cost of foreman = $167 for job, or $0.418 per cu. yd.

Cost of backfill, assuming 1.50 cu. yd. per man per hr., is $\dfrac{0.50}{1.50} = \$0.333$ per cu. yd., or $100 for the job.

Assuming eight men in gang, time required will be $\dfrac{300}{8 \times 1.5} = 25$ hr.

Cost of foreman for the backfill = $25 for job, or $0.0883 per cu. yd.

Now there were 400 − 300 or 100 cu. yd. of special excavation to be hauled away. Using auto trucks, and assuming that this material is shoveled into the trucks as it is excavated, it will require $\frac{2 \times 60}{8 \times 0.30}$ or 50 min. to load a truck with 2 cu. yd. Total time of auto truck for one round trip equals $50 + 17.25 + 0.50 = 67.75$ min.

Cost per load $= \frac{3.50 \times 67.75}{60} = \$2.371$.

Cost per cubic yard $= \frac{2.371}{2} = \$1.186$.

Total cost of special excavation and backfill = \$667 + \$167 + \$100 + \$25 + \$119 + \$162 (overhead) + \$124 (profit) = \$1364 or a cost of \$3.41 per cu. yd. based on 400 cu. yd.

Total cost of general and special excavation and backfill = \$15,484 + \$1364 = \$16,848 for the job.

Cost per cubic yard based on 20,400 cu. yd. = \$0.826.

Exercises.—Make an estimate of the cost of digging a basement 25 × 32 ft. and 6.5 ft. deep in medium soil, assuming 10 per cent to be special excavation. Use drag scrapers with an average haul of 65 ft. Assume wages of man and team at \$1 per hr., and helper and shoveler at \$0.50 per hr. No foreman on the job. Allow 15 per cent for overhead and 12½ per cent for profit. Compute total cost and cost per cubic yard.

Make an estimate of the cost of digging and moving 35,000 cu. yd. of sandy loam using a ¾-cu. yd. steam shovel, and 1½-cu. yd. (net load) dump wagons. Length of haul averages 0.35 mile (0.70 mile for round trip). Assume capacity of shovel at 1.5 cu. yd. per min. (loading 1 wagon each minute) and cost at \$4.50 per hr. Cost of man, team, and wagon is \$1.10 per hr. Assume foreman at \$1 per hr. Allow 17 per cent for overhead and 8 per cent for profit. Compute total cost of job and cost per cubic yard. How many teams and wagons would be needed to keep the shovel working at assumed rate?

JOB 42. ESTIMATING FORMS

The unit of measurement for forms should be the actual area in square feet of the surface of the concrete in contact with the form. The estimated cost of the forms should include cost of struts, posts, bracing, bolts, wire, ties, oiling, cleaning, and repairing, but should not include cost of staging and bridging. Forms for each different part of the structure should be listed and described separately. Forms for moldings, window sills, and copings are measured by the lineal foot. No deductions in form measurement are made for openings having an area of less than 25 sq. ft., because the extra labor in forming around the openings will often cost more than the value of the lumber saved. No allowance is made for construction joints except in very large structures such as dams.

Forms for	How measured
Floors	Total area in square feet.
Walls	Total area in square feet. Forms may be placed on one or both sides.
Columns	Circumference of the column in feet times the net height in feet from floor to floor.
Column caps, drops, bands, etc.	Total area in square feet.
Roofs	Total area in square feet. When the slope of the roof with the horizontal exceeds 25 deg., the upper side of the roof requires forms.
Footings	Total area in square feet of concrete surface next to forms.
Beams and girders	Total area in square feet. For a beam this is equal to the net length between columns or supports times the sum of the breadth and twice the depth.
Staging and bridging	No definite rules. Total number of thousand board feet required should be computed.
Moldings and cornices	Total number of lineal feet. Other dimensions should be noted.
Window sills, and copings	Total number of lineal feet. Other dimensions should be noted.
Stairs	Total area in square feet, composed of area of the under side, areas of ends, and areas of risers.

Approximate Materials and Labor per 100 Sq. Ft. of Forms, Assembling and Erecting

Kind of forms	Lumber, board feet	Nails or bolts, pounds	Labor, hours
Footings and piers	200–350	0.7–1.3	5.0–11.0
Walls and partitions	200–270	1.0–1.4	8.0–14.0
Floors	180–280	0.7–1.2	4.0–12.0
Roofs	200–300	0.8–1.3	4.5–14.0
Columns	190–320	0.7–1.4	6.0–12.0
Column caps	200–400	0.8–1.4	8.0–18.0
Beams and girders	300–700	0.9–1.6	9.0–14.0
Stairs	300–600	1.0–1.6	10.0–20.0
Molding and cornice[1]	200–800	0.8–1.8	8.0–20.0
Sills and lintels[1]	250–800	0.8–1.6	7.5–16.0

[1] Per 100 lin. ft.

Staging and bridging should be estimated separately for each job, and no general values for this work can be given.

Stripping and cleaning of forms will require from 2 to 5 hr. of time per 100 sq. ft. of forms.

When the work permits re-use of forms of certain types, perhaps from 40 to 80 per cent of these forms may be re-used after repairs have been made. The amount of labor required for repair of forms varies greatly and may be estimated at from 2 to 5 hr. per 100 sq. ft. of forms. The extra lumber for form repairs may vary from about 40 to 200 bd. ft. per 100 sq. ft. of forms.

After old forms are repaired, they must be erected before use, and the labor of erecting will be from 25 to 50 per cent of the total time of assembling and erecting new forms.

Form work is often all done by carpenters, but, when possible, a combination gang of carpenters, "handy men," and ordinary laborers should be used to save expense. The proportion of the different classes of laboring men will vary in any gang, but one-third carpenters, one-third handy men or rough carpenters, and one-third laborers will not be far from the average.

The cost of form lumber may vary from about \$30 to \$60 per thousand feet board measure, with average values of from \$35 to \$50.

The average cost of laborers will be about as follows: carpenters \$0.80 to \$1.50 per hr.; handy men or rough carpenters \$0.50 to \$1 per hr.; and laborers from \$0.40 to \$0.60 per hr.

Foremen will cost \$1 to \$2 per hr. and a good superintendent from \$1.50 to \$3 per hr.

Overhead, labor insurance, etc. will vary from 10 to 20 per cent of the total cost, with 15 per cent as an average value. When based on labor costs alone, overhead costs will vary from 15 to 40 per cent.

Profit on form work (when figured separately) will usually vary from 10 to 25 per cent.

When there is no salvage value to the old form lumber, the total costs will usually be higher and the percentage of profit less. When some of the form lumber may be salvaged, it is often difficult to estimate this value, and the estimator may guess at a low salvage value and a low percentage of profit or vice versa. When forms are stripped, the salvage value of the old

form lumber may be from 20 to 90 per cent of its original cost, depending upon care exercised by the stripper, and the possible use to which the old lumber is to be put.

Nails and bolts will cost from about $0.04 to $0.06 per lb. on the average, when purchased in quantity.

Oil for oiling forms will cost a few cents per 100 sq. ft. of surface, say from $0.03 to $0.07, depending on kind and price of oil.

Exercises.—Make a complete estimate of the form lumber required in 1000 bd. ft., pounds of nails and bolts, labor in hours, and costs of each for the following form surfaces: foundations and footings 785 sq. ft.; walls 2180 sq. ft.; columns, 3150 sq. ft.; column heads 1780 sq. ft.; floors 14,200 sq. ft.; beams 3160 sq. ft.; roofs 4100 sq. ft. Take unit prices as follows: Form lumber $38 per thousand board feet delivered at the job, bolts and nails $0.05 per lb., foreman $1.50 per hr., carpenters $1 per hr.. handy men $0.75 per hr., and laborers at $0.50 per hr. Assume that salvage value of form lumber will be 65 per cent. Allow 15 per cent of total cost for overhead and 10 per cent for profit. Forms are to be made and erected and later stripped and cleaned.

JOB 43. ESTIMATING CONCRETE

In estimating concrete quantities, it is customary to use a sheet or page for each different mix, arranging columns on each page about in the following order:

Description (footing, beam, etc.).

Dimensions (of each unit in feet).

Volume (cubic feet or cubic yards).

Other columns may be added for unit and total prices, etc.

In "taking off" quantities of concrete it is customary to begin at the bottom or one end of the structure and go over it systematically. In a concrete building, the order of "take off" would be about as follows:

Footings.

Foundation walls.

Columns (interior and exterior). (Ordinary column caps and brackets are usually included with columns.)

Floor and roof slabs.

Drop panels.

Beams and girders (exterior and interior).

Partitions.

Window sills and copings.

Stairs.

Sidewalks and drives.

In general, all concrete is measured net, as fixed or placed in the structure. Units of measurement are cubic yards or cubic feet, cubic yards being the common unit. No deductions are made for steel beams and reinforcement in the concrete unless the steel has a cross-sectional area of more than 1 sq. ft. No deductions are made for pipes or holes having a sectional area of less than 1 sq. ft. Each mix of concrete should be measured and described separately, and the concrete in different members of the structure should be measured and described separately according to location or purpose of the work.

Many rules are given for measuring stairs, but the best rule is to compute the quantity of concrete required in cubic yards by some simple method.

Sidewalks and pavements should be measured by the square foot or square yard with the thickness and mix stated.

The unit of measurement for precast concrete work is usually the cubic foot.

Curbs, gutters, window sills, lintels, moldings, and such work are often measured per lineal foot, other dimensions being given.

Concrete finishing is measured by the square foot or square yard of finished surface.

After the "take off" has been completed, and the total yardage for each mix totaled, the quantities of cement, fine and coarse aggregates should be computed by means of the formulas given in Job 12 for computing quantities of materials for concrete. The following table gives the quantities of material required for some of the common mixes:

MATERIALS REQUIRED FOR 1 CU. YD. OF CONCRETE

Mix by volume	Cement sacks	Fine aggregate, cubic yards	Coarse aggregate, cubic yards
1:1 :2	10.50	0.39	0.78
1:1½:3	7.64	0.425	0.85
1:2 :4	6.00	0.445	0.89
1:2½:5	4.94	0.46	0.915
1:3 :5	4.67	0.52	0.865
1:3 :6	4.20	0.465	0.935
1:4 :8	3.23	0.48	0.96

To get cement in barrels, divide number of sacks by 4.

The amount of water required will vary from 9 to 15 gal. per sack of cement, or from about 30 to 150 gal. per cu. yd. of concrete, depending upon the water-cement ratio and the water used for washing mixer and equipment and wastage. About 100 gal. per cu. yd. of concrete is a good value for estimating purposes.

The cost of materials delivered on the job is generally used, though on very large jobs the cost of cement will be the price at the mill plus costs of freight, unloading, trucking to job, storing, inspection and testing, and loss due to waste and spoiling. From the cost of cement in cloth sacks there should be deducted 10 cts. for each good cloth sack returned to the mill or dealer. As a general rule, about 10 per cent of the cloth sacks will be wasted. When the cement comes in bulk or in paper sacks, there will, of course, be no credit for returned sacks. Quotations of prices usually given by cement companies are for the cost of cement f. o. b. cars at the station near which the job is located. To this price must be added the cost of testing, unloading, and trucking. Average cost of cement (without sacks) will be from \$2 to \$3 per bbl. for large quantities, or \$0.50 to \$0.75 per sack.

Assuming \$0.65 per sack, or \$2.60 per bbl., the cost of cement at the job will be about as follows:

Cost of Cement

Item	Per sack	Per barrel
Cement f. o. b. cars	\$0.65	\$2.60
Cotton sacks	0.10	0.40
Testing	0.01	0.04
Unloading, trucking, and storing about	0.05	0.20
Total	\$0.81	\$3.24
Credit for sacks returned less loss and freight	0.09	0.36
Net cost of cement at job	\$0.72	\$2.88

The cost of sand, gravel, and crushed rock at the job will vary greatly in different localities. The following are approximate prices only, and for relatively large quantities:

Cost of Aggregate

Material	Weight per cubic yard, pounds	Price per ton, dollars	Price per cubic yard, dollars
Sand	2700	1.10–2.50	1.50–3.40
Gravel	2700	1.50–2.50	2.00–3.40
Crushed stone	2500	1.80–3.00	2.25–3.75

The cost of water can best be found by finding the local rate per 1000 gal. and multiplying this rate by the number of thousand gallons required. In most localities there are also extra charges for setting the water meter and turning the water on and off.

The amount of labor hours required to mix and place a cubic yard of concrete varies greatly according to the nature of the job and conditions of the work, kind of plant, and skill and inclination of the workers.

The following are approximate values:

Labor Required to Mix and Place Concrete

Kind of work	Labor per cubic yard of concrete in hours
Footings	3 to 6
Columns and thin walls	4 to 7
Thick walls	2 to 5
Thin floors and pavements less than 5 in. thick	3 to 6
Thick floors and pavements more than 5 in. thick	2 to 5
Stairs	4 to 8

If the mixing is done by hand, from 1 to 2 labor hr. per cu. yd. of concrete must be added.

With the foreman at $1 to $2 per hr., mixer operator and other skilled labor $0.75 to $1.50 per hr., and ordinary labor at $0.50 to $1 per hr., the average cost of labor for mixing and placing 1 cu. yd. of concrete will vary from about $1.75 to $4.50.

The plant cost of mixing and placing 1 cu. yd. of concrete will vary considerably, depending upon the kind and conditions of the work, arrangement of the plant, amount of plant, and efficiency of

plant operation. In general, a large plant will result in less labor per cubic yard of concrete, and vice versa.

Plant costs per cubic yard of concrete at present writing will vary from about $1.25 to $3 per cu. yd. In general, the unit plant costs on large jobs, say from 8000 cu. yd. or over, are less than those on smaller jobs ranging from 2000 to 6000 cu. yd., other things being equal. An elaborate complete plant will tend to cost more per cubic yard of concrete than a simple plant will, but the saving on labor costs may more than offset the extra plant costs.

Plant costs include not only the mixer costs, but also the costs of barrows, shovels, and concreting tools, carts, hoists, towers, bins, buckets, chutes, runways, etc. Mixer costs alone may vary from about $0.40 to $1.25 per cu. yd.

Overhead charges on mixing and placing concrete work may include cost of labor and other insurance, superintendent, timekeeper, night watchman, general office expenses, telephones, stationery, sundries, etc. Cost of foreman is usually included in labor costs.

Exercises.—Compute total cost of materials, and the mixing and placing of 1650 cu. yd. of concrete, assuming the following:

Mix is 1:2:4 by volume:

Cost of cement per sack at job..................	= $0.78
Cost of sand per cubic yard at job...............	= $2.10
Cost of crushed rock per cubic yard at job........	= $2.45
Cost of water per 1000 gal......................	= $0.10
Cost of plant per cubic yard of concrete..........	= $1.90
Labor hours per cubic yard of concrete...........	= 4.50 hr.
Average cost of labor per hour in concrete gang....	= $0.80
Overhead expense............................	= 16 per cent
Profit.....................................	= 10 per cent

Also compute the cost of each item and the total cost per cubic yard of concrete.

JOB 44. ESTIMATING STEEL FOR REINFORCEMENT

Steel for reinforcement should be estimated in pounds, assuming that a square bar 1 × 1 × 12 in. long weighs 3.4 lb. In the "take off," reinforcing bars should be listed with reference as to whether they are plain bars, deformed bars, spirals, round or square bars of different diameters, bent bars, or straight bars,

and also with reference to the places where they are to be used. Chairs, ties, pipe sleeves, clamps, units, threaded ends, turn buckles, etc. should be tabulated separately. Wire cloth, expanded metal, and similar steel fabric sold by the roll or sheet should be measured and described by the square foot, stating size of mesh and weight per square foot. Allowances should be made for waste, cutting, laps, etc.

The "take off" sheet for reinforcing steel should have columns for size of bar, number of pieces, length, and bends. The summary sheet should give size of bar, weight per lineal foot, total weight, bends, unit price, and total price. Separate sheets should be prepared for plain and deformed bars, spirals, stirrups, and for accessories, such as chairs, ties, clamps, etc.

Weights of Bars in Pounds per Foot of Length

Diameter, inches	Round	Square	Diameter, inches	Round	Square
¼	0.17	0.21	1⅛	3.38	4.30
⅜	0.38	0.48	1¼	4.17	5.31
½	0.67	0.85	1⅜	5.05	6.43
⅝	1.04	1.33	1½	6.01	7.65
¾	1.50	1.91	1⅝	7.05	9.98
⅞	2.04	2.60	1¾	8.18	10.41
1	2.67	3.40	2	10.68	13.60

Unit base prices of reinforcing steel vary at the time of writing from about \$3 to \$4 per 100 lb. for bars of ¾ in. in diameter, and larger. Bars of smaller diameter, or of a length less than 5 ft., are a little higher in price. Small special discounts are often given for ton lots or more. Deformed bars cost a little more than plain bars.

Extra Prices on Steel Reinforcement Bars

Per 100 lb. or fraction thereof, according to size

Size, inches	Price	Size	Price
¾ and larger.....	Base	⅜	Base + \$0.25
⅝ to 11/16........	Base + \$0.05	5/16	Base + \$0.35
½ to 9/16........	Base + \$0.10	¼	Base + \$0.50
7/16..............	Base + \$0.20		

EXTRA PRICES ON STEEL REINFORCEMENT BARS
Per 100 lb. or fraction thereof, according to length

Length	Extra price
5 ft. or over.........	None
Over 4 ft. and less than 5 ft	\$0.05
2 to 4 ft., inclusive.	\$0.10
1 ft. to 1 ft. 11 in., inclusive.	\$0.20
Under 1 ft., not less than.....	\$0.30

Steel bars in other than ⅛-in. sizes are rarely kept in stock by most dealers, hence the estimator and designer should not use 1/16-in. sizes.

TIME IN HOURS REQUIRED FOR MAKING 100 EIGHTH OR QUARTER BENDS

Diameter of bar, inches	Hand bending, hours	Machine bending, hours
½ or less...............	2.00–4.00	0.75–1.50
¾ and ⅞...............	2.50–5.00	1.00–2.00
1 and 1⅛...............	3.25–6.00	1.25–2.50
1¼ and 1½.............	4.00–7.00	1.50–3.00

TIME IN HOURS REQUIRED FOR PLACING 100 BARS

Diameter of bar, inches	Length of bar		
	Under 10 ft.	10 to 20 ft.	20 to 30 ft.
	Time required in hours		
½ or less................	3.5–6.0	5.0– 7.0	6.0– 8.0
¾ and ⅞.....................	4.5–7.0	6.0– 8.5	7.0– 9.5
1 and 1⅛....................	5.5–8.0	7.0–10.0	8.5–11.5
1¼ and 1½	6.5–9.0	8.0–12.0	10.0–14.0

The bending and placing of steel reinforcement bars may be done by handy men at an hourly wage of from \$0.50 to \$1, under the direction of a competent foreman (wage \$1 to \$2 per hr.). In

localities where union rules require a certain class of laborers, the wages of the laborers will probably be from $1 to $1.50 per hr.

In regard to chairs, spacers, ties, etc., the total cost of these will vary greatly, depending on the kind used and the number required. An allowance of from $0.15 to $0.50 per 100 lb. of reinforcing bars is usually satisfactory.

Exercises.—Compute the weights and costs of the following reinforcing steel, using a base price of $3.65 per 100 lb. Allow 35 cts. per 100 lb. for chairs and ties.

Size of rods	Lineal feet			Bends	Number of bars		
	0–10 ft.	10–20 ft.	20–30 ft.		0–10 ft.	10–20 ft.	20–30 ft.
3/8 in. (round).........	106	612	274	None	14	44	16
5/8 in. (round).........	318	948	0	86	42	66	0
3/4 in. (round).........	462	894	316	56	57	52	28
1 1/8 in. (round)........	746	1264	836	72	96	74	38
1/2 in. (square)........	...	186	....	12	..	14	
1 in. (square).........	...	192	....	8	..	12	
3/8 in. (round) for spirals	...	...	2856	None			

Compute the cost of bending and placing the steel, in the previous question, assuming that all work is done by a gang of three handy men and a foreman. Foreman's wage is $1.50 per hr., and wage of handy men is $0.85 per hr. The 2856 ft. of 3/8-in. round bars for spirals will be assumed to be in 36 units, all bent in spiral form ready to be placed in column forms. No labor allowance need be made for placing the spirals in the column forms and tying them to the column rods, as this labor is included in the labor estimate for placing column rods. Allow 18 per cent for overhead.

Compute the total cost of the steel of the previous two exercises all placed in forms. Allow 11 per cent for profit. Compute cost of steel per 100 lb. and per ton (of 2000 lb.) in forms.

JOB 45. ESTIMATING FINISHING OF CONCRETE SURFACES

The cost of finishing concrete surfaces varies according to the price and quantity of materials used, kind of finish desired, labor hours required, labor wage per hour, and speed at which the men work.

The following values are approximate and will vary greatly in different localities:

Work	Labor, hours	Cost, dollars
Troweling floors, walls, sidewalks, etc. (100 sq. ft.)	2– 5	1.50– 5.00
Troweling plain base, cove, etc. (100 lin. ft.)	2– 5	1.50– 5.00
Troweling fancy base, cove, etc. (100 lin. ft.)	3– 6	2.00– 6.00
Carborundum rubbing of floor and wall surfaces (100 sq. ft.)	4–10	3.00–10.00
Carborundum rubbing of window sills, base, cove, etc. (100 lin. ft.)	4–10	3.00–10.00
Ornamental tooling (100 sq. ft.)	8–16	6.00–15.00
1 in. granolithic finish laid after concrete has hardened, including materials and labor (100 sq. ft.)	7–12	7.00–14.00
1 in. granolithic finish laid integral with the concrete, including materials and labor (100 sq. ft.)	4– 8	5.00– 8.00
Scrubbing surface (100 sq. ft.)	2– 5	1.50– 4.00
Washing surface with acid (100 sq. ft.)	2– 5	1.50– 4.00
Sand blasting surface (100 sq. ft.)	3– 5	2.25– 5.00
Cement surface wash per coat including materials (100 sq. ft.)	2– 5	2.50– 5.00

A 1-in. granolithic finish will require, per 100 sq. ft. of surface area, 1 to 1.25 bbl. of cement, and from 700 to 1000 lb. (about 7 to 10 cu. ft.) of aggregate. The aggregate may be part sand and part fine-crushed stone, or all fine-crushed stone with no sand.

In concrete finish work, from 12 to 20 per cent must be added for various overhead expense.

Exercises.—Estimate cost of finishing 1275 sq. ft. of surface by the following methods:

Method	Labor hours per 100 sq. ft.	Hourly wage
Carborundum rubbing	6.20	$0.85
Ornamental tooling	10.50	$0.95
Washing with acid	3.40	$0.90

Allow 16.5 per cent for overhead and assume this figure to cover cost of materials.

JOB 46. ESTIMATING MISCELLANEOUS ITEMS

In the average concrete structure, there are frequently many items other than the excavation and the concrete work. Many of these items are given in the paragraphs which follow, together with their estimated costs. These cost estimates are approximate only, and will vary greatly due to locality, material, wages, and efficiency of laborers.

The approximate cost of brick work in place varies from about \$30 to \$75 per thousand brick. This includes cost of brick, mortar, labor, and scaffolding. Costs of laying vary from about \$20 to \$40 per thousand. In order to estimate the approximate number of brick, the following table is suitable for standard size brick ($2\frac{1}{4} \times 3\frac{7}{8} \times 8$ in.) laid with $\frac{1}{4}$-in. joints:

Thickness of wall	Estimated number of brick per square foot of wall surface
4 in.—1 standard brick width	7
8 in.—2 standard brick width	14
12½ in.—3 standard brick width	21
17 in.—4 standard brick width	28

When estimating the number of brick, deductions for window and door openings are made only for about 50 per cent of their area, due to wastage of brick in cutting and fitting them around the openings. In estimating the labor, no deductions are made because of the extra labor in cutting, fitting, and laying the brick around these openings. The labor of laying a thousand of brick decreases with the thickness of the wall.

Terra cotta partitions will vary in cost from \$20 to \$30 per 100 sq. ft. of wall surface.

Concrete block masonry will cost from \$45 to \$75 per 100 block in the wall, assuming total labor and mortar costs of laying 100 blocks to vary from \$8 to \$15, and the blocks to cost from \$35 to \$60 per 100 delivered at the job. The average size of a block in the wall is about 16 in. long × 8 in. wide × 8 in. high. The

number of blocks of this size per 100 sq. ft. of wall surface will be about 115 (allowing a few for wastage) for an 8-in. wall.

The cost of plastering will vary to some extent on the cost of materials, labor wages, and labor efficiency. On many jobs, the lathing and plastering are let as subcontracts.

Item	Cost per 100 sq. yd.
Wood lath in place	$15 to $30
Metal lath in place	20 to 40
Two-coat plaster in place	30 to 60
Three-coat plaster in place	40 to 75

Hence the total cost of a two-coat plaster job on wood lath would vary from $45 to $90 per 100 sq. yd.

Steel sash without glass cost from $30 to $50 per 100 sq. ft. of opening.

Wood sash without glass cost from $15 to $30 per 100 sq. ft. of opening. With glass, the cost is $35 to $65 per 100 sq. ft. of opening.

Glass and glazing cost from $20 to $35 per 100 sq. ft. Glass area is often assumed as 90 per cent of sash area.

The cost of a single door and frame in place, complete with hardware, will vary from about $20 to $60. A pair of French doors with frame and hardware in place will cost from $75 to $125.

Baseboards, molds, and other wood trim in place cost from $15 to $30 per 100 lin. ft.

Tongue and grooved flooring in place will cost from about $18 to $30 per 100 sq. ft. of floor area. Rough flooring 1 in. thick will cost about half as much.

No general estimate of cost can be made for light iron work and miscellaneous iron work.

Flashing may be estimated at from $30 to $100 per 100 lin. ft. depending on kind and weight of material, copper flashing being the most expensive.

Metal roofing in place will cost from $15 to $25 per sq. of 100 sq. ft. of roof surface for iron or tin, and about three times as

much for copper. All metal flashing and roofing is usually let as a subcontract.

A composition roof (tar and paper) covered with gravel will cost from \$10 to \$20 per 100 sq. ft. of roof surface.

The cost of good composition shingles in place will vary from about \$15 to \$30 per 100 sq. ft. of roof surface.

The cost of good wood shingles in place will cost from about \$12 to \$30 per 100 sq. ft. of roof surface.

Cost of stucco per 100 sq. yd. varies greatly with the materials used, number of coats, thicknesses of coats, wood or metal lath, wages, and efficiency of labor. The cost of lath and stucco in place may vary from \$50 to \$125 per 100 sq. yd.

The cost of painting varies greatly in regard to quality of paint, kind of surface to be covered, number of coats, wages, and efficiency of workmen. Average prices are from \$1.50 to \$3 per 100 sq. ft. for one coat. Two-coat work will cost from \$2.75 to \$5.50 per 100 sq. ft.

Cleaning up the job costs from about $\frac{1}{10}$ of 1 per cent to $\frac{1}{2}$ of 1 per cent of the total cost.

Plans and specifications cost from $2\frac{1}{2}$ to 3 per cent of the total cost.

Cost of inspection varies from 2 to 3 per cent of the total cost.

Liability insurance varies from 5 to 10 per cent of the labor cost.

Sundries vary from about 2 to 5 per cent of the total cost.

General overhead expenses including office expenses, traveling expenses, job overhead superintendence, timekeeper, office clerks and stenographers, draftsmen, watchmen, telephones, freight, stationery, interest, insurance, etc., may vary from 10 to 20 per cent of total cost.

Profit is usually estimated at from 8 to 15 per cent depending on the conditions governing the particular job.

Such items as lathing and plastering, metal roofing and flashing and other metal work, heating, plumbing, lighting, painting, etc. are frequently let as subcontracts. Plumbing fixtures cost from \$60 to \$100 per fixture, heating from \$75 to \$125 per radiator for steam and hot-water heat, and from \$50 to \$75 per hot air register for hot air heat, lighting from about \$5 to \$12 per drop or light outlet with fixtures extra.

Summarizing, the items of cost of a concrete structure to the owner may be listed as follows.

Architect's fees and commission.

Main contract, including excavation, forms, concrete, steel, finish, cleaning up, sundries, overhead, and profit.

Subcontracts—if let separately.

Extras.

Land, including proving of title, etc.

Interest and insurance during construction.

Cost of financing.

Profit to owner, if he sells.

Exercises.—On what items does the cost of brick work depend?

What items are usually let as subcontracts in concrete building construction?

Which wall would be cheaper: an 8-in. brick wall with brick costing $28 per thousand and complete labor and mortar costs of laying brick in wall of $34 per thousand, or an 8-in. concrete block wall made with blocks about 8 × 8 × 16 in. in size and costing 45 cts. each on the job, and complete labor and mortar costs of laying block in the wall of $12 per 100 blocks?

JOB 47. SQUARE AND CUBE METHODS OF ESTIMATING BUILDING COSTS

While the only safe and sure means of estimating is to take off actual quantities of materials and hours of labor, and use the local unit prices prevailing in order to determine the total cost of the structure, many experienced estimators use the approximate methods of estimating certain types of structures by the cube or square, in order to obtain approximate costs in a short time, and also as a comparison and rough check on the costs found by the more accurate methods.

The method of estimating by the square of 100 sq. ft. or 1 sq. ft. of floor area is applicable to office buildings, schools, mills, warehouses, factories, hospitals, churches, stores, residences, and garages. This method is useful in comparing the costs of different buildings, where the floor area is important, as in offices and factories, and in determining the capacities and costs per person, as in schools, churches, and hospitals.

There are several variations in estimating buildings by the square. One method is to allow a certain figure per square foot for each floor, and use other figures for the roof and foundation

areas. Another method is to use different unit prices for the different floors—the lower floor to include cost of foundations, and the upper floor to include cost of roof. A third method is to use the same unit price per square foot of floor area for all floors, omitting the roof area or both the roof and basement areas.

The method of estimating building costs by the cube or volume is more accurate, in general, than the method of estimating by the square. The best method of estimating by the cube is to find the total volume of the building in cubic feet, and multiply this volume by a selected unit price per cubic foot for this particular class of building. Another method is to use a certain unit cost per cubic foot for the part of the building that is more expensively finished, and another price for the portions that are more cheaply or less completely finished. For example, in a residence, the cubic contents of the basement, attic, and garage would have one unit price, and the living-room, dining-room, kitchen, halls, bath, and bedrooms would have another unit price. A third method is to consider only half or two-thirds of the volume of the basement, attic, and garage, when computing the cubic contents of a residence, and then use the same price per cubic foot for all parts of the building. Of course, buildings of different types and kinds of construction would require different unit prices per cubic foot.

Exercises.—A certain building is 40 × 60 ft. in size and consists of basement, first, second, and third floors, and attic. Assume heights (including floor thickness) of 8.5, 10, 9, and 9 ft. for basement and the first, second, and third floors, respectively, and an average height of 7.5 ft. for the attic. Cost of building was $44,270.

Compute the cost per square foot by each of the following methods:

1. Based on the floor area of the three floors.
2. Based on total area of three floors, basement, and roof, assuming roof area equal to one floor area.
3. Based on area of three floors and basement.
4. Based on area of three floors, assuming that the cost of the first floor is 1.60 times the cost of the second, and that the cost of the third floor is 1.50 times the cost of the second.

Compute the cost per cubic foot by each of the following methods:

5. Based on the total volume of the building in cubic feet.
6. Allowing full value for the three stories, 60 per cent of the value for the basement, and 50 per cent of the value for the attic.

Note.—Take cubic feet for the three stories, and add 60 per cent of the cubic feet in the basement and 50 per cent of the cubic feet in the attic.

JOB 48. SAMPLE QUANTITY ESTIMATE FOR CONCRETE WORK

In this job, a sample quantity estimate will be made of the materials and labor required for the reinforced concrete slab shown in Fig. 71, page 140. It will be assumed that the estimates have been previously prepared for the abutments.

The estimate will be divided into four parts: forms, steel, concrete, and surface finish. A "take off" of the quantities will be made first, and then an estimate of the labor will be given. It is to be remembered, that all labor estimates are approximate only.

Forms.

Under side of floor slab $= 30 \times 16 = 480$ sq. ft.

Ends of floor slab (allowing for pavement notch)

$$= 2 \times 30 \times 1.5 = 75 \text{ sq. ft.}$$

Sides of floor slab $= 2 \times 16 \times 2 = 64$ sq. ft.

Railings, two rails, sides and ends

$$= (2 \times 2 \times 3 \times 19) + (2 \times 2 \times 3 \times 1) = 228 + 12 = 240 \text{ sq. ft.}$$

Total square feet of form surface

$$= 480 + 75 + 64 + 240 = 859 \text{ sq. ft.}$$

In determining the number of board feet required per 100 sq. ft. of form surface, it should be noted that the form lumber must be of selected lumber carefully fitted together and rigidly braced. This means that there will be considerable wastage even under the most favorable conditions. The shoring for the slab, and the paneling of the railing will require considerable lumber. An allowance of 525 bd. ft. of lumber will be made for each 100 sq. ft. of form surface for this estimate. This can be checked, when a bill of materials is made for the form lumber.

Total lumber for forms will be $\frac{525 \times 859}{100} = 4500$ bd. ft. of lumber.

Allowing 1.5 lb. of nails and bolts per 100 sq. ft. of form surface gives $1.5 \times 8.59 = 13$ lb. nails and bolts.

The hours of labor required per 100 sq. ft. of form surface will be comparatively large, due to the care with which the forming must be done. For this estimate, 12.5 labor hr. per 100 sq. ft. of forms will be assumed for assembling and erecting, and 3.5

labor hr. per 100 sq. ft. of form surface for stripping and cleaning forms. Labor hours for forms =

$$(12.5 + 3.5) \times 859/_{100} = 137.5 \text{ labor hr.}$$

Concrete Materials.- The number of cubic yards of concrete required is given in Fig. 71 as 27.5 cu. yd. A check will be made of this quantity as follows:

Floor slab	$= 18.5 \times 30 \times 1.125$	$= 625$ cu. ft.
Rails	$= 2 \times 3.75 \times 0.833 \times 18.5$	$= 115$ cu. ft.
Curb	$= 2 \times 0.75 \times 0.50 \times 18.5$	$= 14$ cu. ft.
Total		754 cu. ft.
Deduction for pavement notch	$= 2 \times 27 \times 1 \times 0.33$	$= 18$ cu. ft.
Net concrete		736 cu. ft. = 27.3 cu. yd.

There is no allowance here for wastage or possible slight overrun. Will use 27.5 cu. yd. in estimating materials, and add about 5 per cent for wastage.

Materials required for 27.5 cu. yd. of Class *A* concrete of 1:2:4 mix, are:

Sacks of cement

$$= \frac{27.5 \times 42}{1 + 2 + 4} = 165 \text{ sacks, assume } 168$$

Cubic yards of sand

$$= \frac{27.5 \times 1.55 \times 2}{1 + 2 + 4} = 12.2 \text{ cu. yd., assume } 13$$

Cubic yards of stone or gravel

$$= \frac{27.5 \times 1.55 \times 4}{1 + 2 + 4} = 24.4 \text{ cu. yd., assume } 26$$

The water required will be approximately 2750 gal.

The values assumed allow for about 5 per cent wastage. The wastage of aggregates will usually be a little more than that of cement.

The labor hours required to mix and place concrete in a bridge will be comparatively high, possibly from 4 to 7 hr. per cu. yd. of concrete. The roadway surface must be finished as it is laid.

For this job, 5.5 hr. of labor per cu. yd. of concrete will be assumed. Total labor hours required for mixing and placing concrete will be 5.5 × 27.5, or 151 hr.

Consideration of the concrete plant will be made in the cost estimate. The plant and crew must be large enough, so that all of the concrete for the slab bridge, except railings, can be placed in 1 day. A 2- or 3-bag (1/3 to 1/2 cu. yd.) batch mixer would do. The mixer will be used about 2 days.

Reinforcing Steel.—The Bill of Bars given in Fig. 71 may be taken as correct, and the total weight checked.

Number	Mark	Size	Length, feet	Total length, feet	Weight per foot, pounds	Total weight
33	*S1*	7/8-in. round bars	18.00	594	2.04	1212
32	*S2*	7/8-in. round bars	18.25	585	2.04	1193
26	*S3*	1/2-in. square bars	4.75	124	0.85	105
10	*S4*	1/2-in. square bars	18.00	180	0.85	153
17	*S5*	1/2-in. square bars	29.75	506	0.85	430
Total weight						3093 lb.

For chairs, spacers, and ties for bars assume about 125 lb

The number of bends is as follows:

Mark	Size	Number of bends
S1	7/8-in. round bars	132
S2	7/8-in. round bars	64
S3	1/2-in. square bars	26
Total		222

Labor in hours required for bending steel, assuming hand bending, will be about 3.5 hr. per 100 bends, giving a total of 3.5 × 222/100, or about 8 hr.

The labor of placing the bars may be estimated as follows:

65	$S1$ and $S2$	$\frac{7}{8}$-in. round bars at 7 hr. per 100 = 4.55 hr.
26	$S3$	$\frac{1}{2}$-in. square bars at 6 hr. per 100 = 1.55 hr.
10	$S4$	$\frac{1}{2}$-in. square bars at 6 hr. per 100 = 0.60 hr.
17	$S5$	$\frac{1}{2}$-in. square bars at 6 hr. per 100 = 1.00 hr.
	Total.......	7.70 hr. (say 8 hr.)

Surface Finishing.—The specifications require a two-coat carborundum rub on the surface of the bridge rails and on the exposed sides of the slab. Total area to be rubbed is approximately as follows:

Rails = 8 × 19.5 × 4 = 624 sq. ft.
Sides = 2 × 2 × 16 = 64 sq. ft.

Total..................688 sq. ft.

Assuming 7 hr. labor per 100 sq. ft. of surface for the first rub coat, and 5 hr. labor per 100 sq. ft. of surface for the second rub coat, the total labor hours for carborundum rubbing will be $(7 + 5) \times 688/100 = 82.5$ hr.

The upper surfaces of the slab floor and curb were finished when the concrete was placed. Removing fins, smoothing surfaces, etc. on the under side of the bridge would require about 12 hr. labor for approximately 500 sq. ft. of surface area.

Summary of Estimate

Item	Materials	Labor
Forms..........	4500 bd. ft. lumber, 13 lb. nails and bolts...	137.5 hr.
Concrete........	168 sacks cement........................	151 hr.
	13 cu. yd. sand	
	26 cu. yd. stone	
	2750 gal. water	
Steel...........	3093 lb. bars...........................	16 hr.
	125 lb. spacers, ties, etc.	
Finishing.......	688 sq. ft. carborundum..................	94.5 hr.
	500 sq. ft. rough	

JOB 49. SAMPLE COST ESTIMATE FOR CONCRETE WORK

A cost estimate will be prepared for the reinforced concrete slab bridge of Fig. 71, for which the materials and labor were estimated in the previous job. Assume that the bridge is located about 3 miles from the source of supply of materials, and that there is a good concrete road from the source of supply to the bridge site. All materials will be purchased from local dealers and delivered at the bridge site. Estimates are to nearest $1.

Cost Estimate

Forms	Materials	4500 bd. ft.	at $42 per thousand	
		less salvage	at $15 per thousand	= $122
		13 lb. nails and bolts		1
	Labor	137.5 hr.	at $0.65 per hr.	= 90
	Total for forms			$213
Steel	Materials	3093 lb. bars	at $0.0365 per lb.	= $113
		125 lb. spacers and ties	at $0.08 per lb.	= 10
	Labor	16 hr.	at $0.60 per hr.	= 10
	Total for steel			$133
Concrete	Materials	168 sacks of cement	at $0.67 per sack	= $113
		13 cu. yd. sand	at $1.95 per cu. yd.	= 25
		26 cu. yd. stone	at $2.20 per cu. yd.	= 57
		Water		5
	Labor	151 hr.	at $0.60 per hr.	= 91
	Plant estimated			40
	Total for concrete			$331
Finishing labor		94.5 hr.	at $0.60 per hr.	= $57
Superintendence and overhead				$125
Profit				$110
Total bid				$996
Cost per cubic yard, 27.5 cu. yd.				$ 36.50

Exercises.—What would the total cost estimate for the reinforced concrete slab bridge have been if:

Lumber cost $39 per thousand with a salvage value of $12 per thousand
Steel cost $0.0352 per lb. delivered on the job.
Cement cost $2.75 per bbl. delivered on the job.
Sand cost $2.05 per cu. yd. delivered on the job.
Good gravel cost $1.90 per cu. yd. delivered on the job.
Overhead and superintendence cost 17 per cent.
Profit is estimated at 10 per cent.
Other prices the same.
Also compute cost of concrete per cubic yard in the completed job.

JOB 50. TIME AND WORK SCHEDULES FOR CONCRETE JOBS

On medium-sized and large concrete jobs, it is advisable to provide time and work schedules for the convenience of the main office, superintendent, and foremen. Such a schedule notes the different construction operations, the estimated dates that each operation should start and finish, and the actual dates. Such a schedule, together with progress reports and charts (if the job is a large one), enables the contractor or engineer to note if the work is progressing as planned, and to observe which items are ahead or behind the schedule.

Certain construction operations and trades should follow each other in regular order and without interference. Confusion, with a resulting loss of efficient work, often occurs, when two comparatively large gangs are scheduled to work on the same part of a job at the same time. Two small gangs may frequently work on the job at the same time (such as plumbers and electricians doing rough plumbing and wiring in a residence), without interference. In general, the paint gang should come last (except for priming coat work) on any section of the job, and after the other gangs have completed their work.

It is not necessary for any one operation to be wholly completed before another operation is started, but the work should be so planned that the different operations do not interfere with each other. For instance, on concrete paving work, the excavation gang should be about a half a day or so in advance of the roller, and the concreting gang should follow about a day behind the roller. This allows the work to go forward efficiently, prevents interference between gangs, and permits the general superintendent or contractor to speed up any gang that is lagging.

In order to note if the work is progressing according to schedule it is usually required that the superintendent, general foreman, inspectors, or timekeepers (depending on to whom the duty is assigned) make a daily report or record of the different kinds and quantities of work done. In addition to making the daily reports or records, a daily diary should be kept by the proper official in which all essentials relating to the particular job are noted. In general, the superintendent or general foreman is the best person for preparing and signing the daily reports.

The following schedule is for the work on a garage building:

TIME AND WORK SCHEDULE

Type of Building *Garage* Location 2463, 1*st St.* Supt.______

Number	Item	Estimated dates		Actual dates	
		Start	Finish	Start	Finish
1	Excavation				
2	Make and erect forms				
3	Bend and place steel				
4	Mix and place concrete				
5	Remove forms				
6	Finish concrete surface				
7	Brick work				
8	Sash, frames, and trim				
9	Glass and glazing				
10	Roofing and flashing				
11	Plumbing				
12	Steam fitting (heating)				
13	Wiring				
14	Cleaning up				
15	Painting				
16	Schedule time of completion				
17	Contract time of completion				

On a one-course concrete paving job, the time and work schedule would include the following items: excavation, rolling subgrade, forming, concreting and finishing, curing, removing forms and cleaning up, finishing shoulders, scheduled time for completion, contract time for completion.

On large jobs, delivery schedules are often provided for all of the materials used, so that there will be no delays due to lack of materials, and, at the same time, there will not be a surplus of materials to cover up the work. Labor schedules are sometimes made showing the numbers of each of the different classes of laborers required on the job for each day.

Exercises.—State advantages of a time and work schedule for a concrete job.

Prepare a time and work schedule for constructing 1900 lin. ft. of 5-ft. concrete sidewalk. All of the walk (slight excavation, forming, and concreting), except curing, must be completed in 5 weeks' time. State assumed dates for schedule time. Excavation work to start on May 1.

JOB 51. PROGRESS REPORTS AND CHARTS

The superintendent or foreman on a concrete construction job should send in to the main office every day a detailed report of the progress of the work in his charge. By this method, the

MATERIALS RECEIVED AND WORK DONE

JOB NO.________ LOCATION____________________

DATE________192__ ____________________SUPERINTENDENT

MATERIALS	ON HAND AT START	RECEIVED	USED	ON HAND AT FINISH
Cement, *(inches)*				
Sand, *(cu.yds.)*				
Gravel, *(cu.yds.)*				
Stone, *(pounds)*				
Lumber, *(board ft.)*				
Nails & Bolts, *(lbs.)*				
Other Items				

LABORERS		HOURS									
		FORMS				STEEL		CONCRETE			CLEAN UP OF JOB
NOS.	RATES	ASSEMBLE	ERECT	STRIP	CLEANED AND REP'D.	BEND	PLACE	MIX	PLACE	FINISH	
1											
2											
3											
4											
5											
6											
7											
8											

WORK DONE

Forms assembled ________ sq.ft.	Forms ________ sq.ft.
Forms stripped ________ sq.ft.	Forms cleaned & repd. ________ sq.ft.
Steel bent ________ lbs.	Steel placed ________ lbs.
Concrete mixed and placed ____ cu.yd.	Concrete surface finished. ____ sq.ft.
Other work ________	________

FIG. 73.—Superintendents' daily report form.

main office is enabled to keep in close touch with the job, and to take any needed steps in regard to the supply of materials and labor. An examination of the progress reports will show whether

the work is progressing at a satisfactory rate in regard to quantities and costs. Figure 73 shows a sample form of daily report required from the superintendent on a concrete job. This report gives a complete summary of materials on hand, received, and used, laborers and their work, and the amount of work of different kinds performed.

The daily reports of the superintendent or foreman should be checked from time to time by the timekeeper or other official, to provide against possible dishonesty and errors

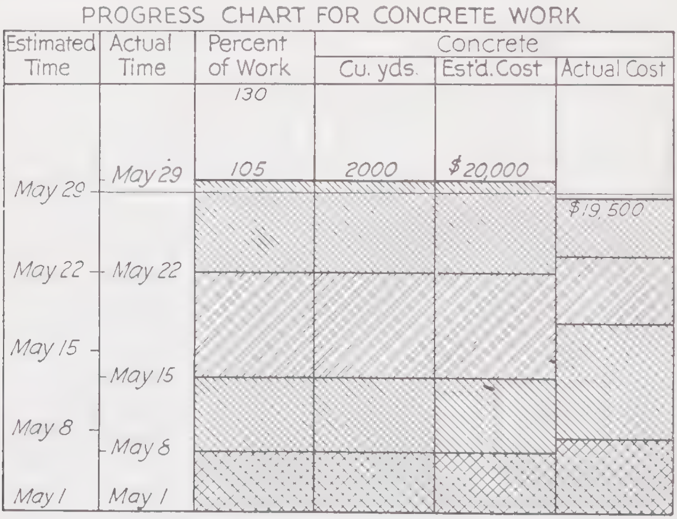


FIG. 74.—Progress chart for concrete work.

So that the owner, contractor, architect, or engineer may clearly and easily visualize the amount of work done, rate of progress of the job, and the cost of the work, progress charts are prepared and kept up to date. A progress chart is a graphical representation of the progress of the work on the job in question. These charts are prepared from the data given in the progress reports and must be kept up to date. A progress chart may be simple or complicated, and show a few or many details, as the case may be. The charts should not be too complicated, or contain too much detail, if they are to be read and understood by the average person.

A simple progress chart for concrete work is shown in Fig. 74. The chart includes estimated time, actual time, per cent of work, cubic yards of concrete, estimated cost, and actual cost. On this one particular job, note that the work lagged for the first 2 weeks while the costs were greater than were estimated. During the last 2 weeks, the work was speeded up and the job finished on time, with an actual cost a little less than that estimated, in spite of the fact that the actual concrete required in cubic yards exceeded the estimated amount by 5 per cent.

Figure 75 shows a time-work schedule for a concrete construction job involving excavation, assembling and erecting forms,

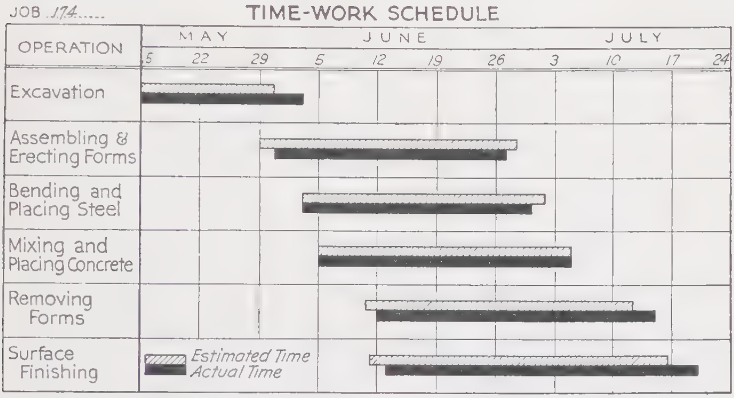


FIG. 75.—Progress chart and time-work schedule.

bending and placing steel, mixing and placing concrete, form removal, and surface finishing. The open (or white lines) show the estimated time, and the full black lines show the actual time required. This chart could be lengthened and elaborated to include as many operations as desired. Another version of this chart is to plot the time required with vertical lines, and plot the operations horizontally.

In Fig. 76, the same data were plotted as in Fig. 75, but are shown in a different manner. The light lines indicate the estimated time, while the actual time is shown by the heavy lines. Note that the actual excavation exceeded the estimated quantity (due to a bank cave in), while the other actual quantities agreed with the estimates. In regard to the time required,

the excavation, form removal, and surface finishing each required a longer time than was estimated, while the erection of forms and steel placing each required less time.

Another variation of the chart shown in Fig. 76 is to use a light black line showing the relation between estimated time and quantity of work in percentages, a heavy black line showing actual time required, and a heavy red line for costs. If, for any operation, the red (cost) line agrees with the heavy black line,

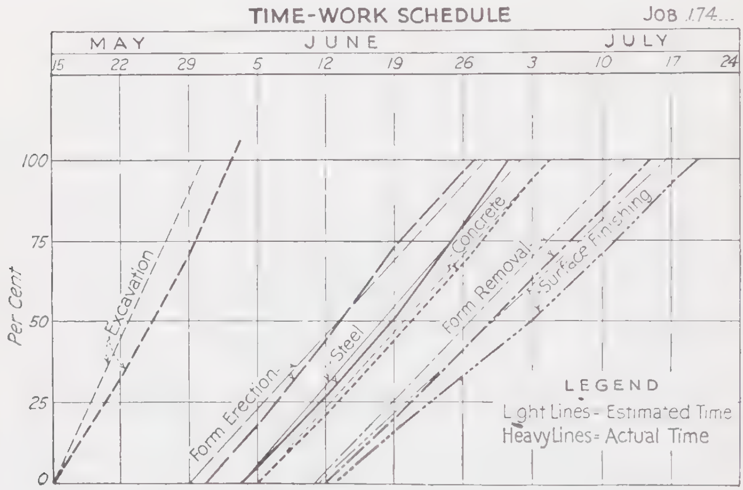


FIG. 76.—Progress chart and time-work schedule.

the estimated and actual costs agree; if the heavy red line is below the heavy black line, the costs are less than were estimated; while, if the red line goes above the heavy black line, the costs are more than were estimated for the corresponding quantity of work. Note that the quantity of work and costs will be expressed in the form of a percentage of the estimated total of each. Actual quantities and costs may be written on the chart adjacent to the corresponding points on the lines, if desired.

Exercises.—Prepare a progress chart showing the following data in a concrete road job:

Excavation, estimated 12,000 cu. yd., cost $1.25 per cu. yd., start Aug. 1, finish Aug. 29.

Forming at sides of road, estimated 11,320 lin. ft., cost 10 cts. per lin. ft., start Aug. 3, finish Sept. 3. Steel forms are used and reused throughout the job.

Concrete, estimated 1885 cu. yd., cost \$12.85 per cu. yd., start Aug. 4, finish Sept. 4.

Progress Reports—totals are given.

Excavation, start Aug. 1; Aug. 8, 2750 cu. yd., cost \$3680; Aug. 15, 5450 cu. yd., cost \$7025; Aug. 22, 8725 cu. yd., cost \$11,100; Aug. 29, 11,200 cu. yd., cost \$13,900; Sept. 1, finish, 12,320 cu. yd. cost \$15,200.

Forming at sides, start Aug. 4; Aug. 8, 1420 ft. cost \$151; Aug. 15, 3230 ft., cost \$347; Aug. 22, 6170 ft., cost \$628; Aug. 29, 9250 ft., cost \$930; Sept. 3 finish, 11,320 ft., cost \$1116.

Concreting, start Aug. 5; Aug. 8, 228 cu. yd., cost \$3030; Aug. 15, 531 cu. yd., cost \$6950; Aug. 22, 1020 cu. yd., cost \$13,420; Aug. 29, 1530 cu. yd., cost \$19,600; Sept. 4, finish, 1891 cu. yd., cost \$24,150.

SECTION V

LABORATORY METHODS

WORK IN THE LABORATORY

Purpose of Laboratory Work.—The purpose of this laboratory work is to give the student a general idea of the physical properties of cements, aggregates, mortars, and concretes, and the various ways of testing them. The student is not expected to become an expert tester upon the completion of the course, but he will be expected to know how the different tests should be made. Considerable experience is necessary before anyone can become an expert in the testing of cements and concretes, and in the correct interpretation of the results. It is only by close observations of the rules and specifications that even this may be accomplished.

Apparatus.—Each student will be held responsible for all apparatus assigned to him. In general, all apparatus needed during the laboratory period should be secured from the instructor at the beginning of the period. All tools, apparatus, tables, etc., should be cleaned immediately after using, and all of the waste material should be deposited in the waste boxes provided for that purpose. Waste material should not be thrown on the floor. Neatness and cleanliness are important elements in all laboratory work.

Making Specimens.—The methods of mixing and molding given in the standard methods and specifications will be followed in all tests as far as practicable. At the beginning of the first laboratory class, the instructor should illustrate the methods of preparing briquette molds and the mixing and molding of briquettes.

Curing Specimens.—All cement, mortar, and concrete specimens will be removed from the molds, marked, and stored according to the requirements of the standard specifications.

Marking Specimens. Each specimen, at the time it is made, or when it is removed from the molds, should be marked, so that it can be identified as to owner, composition, and test. Briquettes should always be marked on the ends. When in doubt, consult the instructor in regard to the proper way of marking the specimens.

Testing.—A student must not use any machine until its principles of operation have been explained to him by the instructor. A good rule for the student is: Do not use any testing machine unless the instructor is present and has given permission. In testing, follow the instructions given in the job sheets and in the standard methods and specifications. Good results can be secured only when the rules governing the operation of the testing machine are strictly followed.

Notebook.—Each student should keep a notebook for use in the laboratory. In this notebook, the student should record the date of making, composition, and marks of the specimens, the dates on which the specimens are to be tested, the data obtained during the tests, and all other observations and data that may be of use in writing reports or in making future experiments.

Efficiency.—In the laboratory students should: (1) try to do good work, and (2) try to do the work in as short a time as practicable. That is, students should try to become both good workers and fast workers. The instructor may, at various times, instruct students in their work so that their efficiency will be improved.

LABORATORY REPORTS

Laboratory Reports.—The laboratory reports required may be written either in a laboratory report book or on loose sheets of typewriter-size paper, and the sheets comprising each report fastened together with clips. If report books are used, the paper in them should preferably be cross-section paper, of about 5 divisions per inch. If loose sheets are used, it is advisable to fasten the sheets inside manila folders. The front cover page of this folder should have on it the title of the test, the student's name, the date that the report is due, and any other information required by the instructor. All reports should be neatly written in ink or typed.

Outline.—The standard outline for a laboratory report is as follows:

1. Title
2. Object
3. Apparatus (and sketches)
4. Method
5. Data
6. Computations
7. Curves
8. Conclusions
9. Answers to questions

Title.—The title should indicate the subject of the experiment or test. In general, the heading given the experiment on the job sheet will be sufficient.

Object.—This is a brief, concise statement of the purpose of the experiment.

Apparatus.—Under this heading include a list of apparatus used and, when required, a neat sketch of some piece of the apparatus. Any special apparatus used should be briefly described.

Method.—Describe briefly how the test was made. If the method is a standard one that has been described in the text, a reference to the text (giving the page number) will be sufficient.

Data.—The data should be tabulated in a neat systematic form. All data should be carefully checked before handing in the report.

Computations.—Sample computations should be included in the report, to show how the main results were obtained from the data. The formulas used and the numerical substitutions in them should always be given in full.

Results of computations should be accurate to 1 per cent. The properties of the specimens tested will rarely be the same as the average properties given in the texts. Results differing greatly from the average values frequently indicate errors in computations.

Curves.—Curves should be drawn on cross-section paper of the same size as the report paper, and having 5, 10, or 20 divisions per lineal inch. The points determining the curve should be shown in small circles (small triangles, squares, etc., may be used, if there be more than one curve). The curve should be carefully drawn with either a straight or a curved ruler. Medium and fine lines are better than heavy ones. When there are only a few points,

straight lines should be drawn connecting these points; but when there are many points, a smooth curve should be drawn. The scales of the coordinates should be plainly marked. The curve sheet should show the title of the experiment and the main results.

Conclusions.—The conclusions should contain a summary of the main results and important facts obtained from the test.

Questions.—All questions asked should be answered in full.

JOB 52. INSPECTION AND SAMPLING OF PORTLAND CEMENT

Object.—To inspect and sample a shipment of portland cement.

Significance.—The securing of a representative sample of cement is essential, if the test results are to indicate correctly the properties of the cement.

References.—Appendix 1.

Inspection.—Observe if the shipment is stored in such a manner that it can be easily inspected and identified, and also observe if the building is weather-tight, and the cement protected from dampness.

The cement may be in bulk, barrels, or bags. If in barrels or bags, note if the brand of the cement and the name of the manufacturer are plainly marked thereon.

Check the weights of several bags (or barrels), and note if the weight requirements of the specifications are met.

Observe if the cement contains lumps, and if the lumps are hard or soft. Soft lumps are comparatively harmless.

Sampling.—Secure a sample as directed in Secs. 16 to 19, inclusive, of Appendix 1. If the cement is sacked, a sample may be obtained by inserting a piece of split tubing through a flap in the bottom of a sack. Metal cans with tight covers or heavy paper sacks are suitable containers for cement samples. The container should be marked so that the sample can be correctly identified.

Report.—Prepare a brief report. This report should include the name of the brand and the manufacturer of the cement, size of shipment (approximate or actual number of bags or barrels), the place of storage, the name of the inspector, the date of the inspection, the results of the inspection as to proper storage, lumps, weights of barrels or bags, etc., whether the sample was an

individual or composite one, size or weight of the sample, the marking on the container of the sample, and any other information that the inspector deems essential.

JOB 53. NORMAL CONSISTENCY OF PORTLAND CEMENT

Object.—To determine the percentage of water required to make a cement paste of normal consistency.

Significance.—The correct percentages of water must be used when mixing the neat cement pastes and the cement mortars, or the test results will not be reliable.

References.—Appendix 1.

Materials.—Portland cement. Note the brand.

Apparatus.—Scales, trowel, graduated cylinder for measuring water, watch, Vicat apparatus, etc.

Vicat Method.—Follow method given in Sec. 39 of Appendix 1. Use about 23 per cent of water for the first trial paste. Record penetration of rod. If this paste is not of normal consistency, make other trial pastes with varying percentages of water until the normal consistency is obtained.

Ball Method. (Old U. S. Government Method).—After mixing a trial paste by the previously described method, quickly form a 2-in. ball of the neat cement paste. Drop the ball, from a height of 2 ft., upon the table top. The cement paste is of normal consistency when the ball does not crack and does not flatten more than one-half of its original diameter. Make trial pastes with varying percentages of water until the normal consistency is obtained.

NOTE.—When a trial paste of normal consistency has been obtained, this paste may also be used for determining the time of set and for making the pats for the soundness test.

Report.—Prepare a tabulation showing the percentages of water used, and the corresponding penetrations of the Vicat rod or the corresponding flattenings of the diameter (expressed approximately in tenths of the original diameter) in the ball test. Note the mixtures which cracked when they were dropped in the ball test.

Questions.—If both methods were used, which method gave the best results? Why?

How will the amount of water in the trial paste affect the strength and setting time of the cement?

Why do different cements require different percentages of water to give normal consistency?

The quantity of cement to be mixed at one time should not be less than 5000 g. or more than 1000 g. Why?

JOB 54. TIME OF SETTING FOR PORTLAND CEMENT

Object.—To determine the time required for initial and final set of a sample of portland cement.

Significance.—The object of this job is to determine the time which elapses from the moment water is added until the paste ceases to be plastic (called the initial set), and also the time which elapses before the paste acquires a certain degree of hardness (called the final set or hard set). The former is the more important, since, with the commencement of setting, the process of crystallization begins. As a disturbance of this process may cause a loss of strength, it is desirable to complete the operation of mixing, molding, or incorporating the mortar or concrete into the work before the initial set occurs.

References.—Appendix 1, and Sec. I.

Materials.—Portland cement. Note the brand.

Apparatus.—Vicat apparatus or Gillmore needles and other apparatus, as in the preceding job.

Method.—Follow the directions given in Sec. 45 to 49 inclusive of Appendix 1. Either the Vicat apparatus or the Gillmore needles may be used for determining the time of set. Be sure to note the time when the water was first added to the cement.

Report.—Note the time required for the initial and final sets of this sample of portland cement.

Questions.—Did this sample of portland cement pass the specifications for the time of setting for portland cement?

Which method of test (Vicat or Gillmore) do you prefer? Why?

What is the effect on construction work of using a quick-setting cement? Of using a slow-setting cement?

If a cement having a flash set is used in concrete, how should this concrete be mixed to overcome the effect of the flash set?

JOB 55. SOUNDNESS TEST OF PORTLAND CEMENT

Object.—To determine the soundness of a sample of portland cement.

Significance.—Portland cement must be sound (that is, must not swell, disintegrate, or crumble) if it is to be used on construction work. The steam test quickly brings out those qualities which tend to destroy the strength and durability of the cement.

References.—Appendix 1 and Sec. I.

Materials.—Portland cement. Note the brand.

Apparatus.—Scales, graduated glass cylinder for measuring water, trowel, watch, glass plates about 4 in. square, and the special apparatus for the steam test, etc. See Fig. 3 of Appendix 1 for an illustration of this special steam test apparatus.

Method.—Follow the method given in Secs. 42, 43, and 44 of Appendix 1. Note that it takes some practice and skill to make a good, smooth, neat cement pat of the correct size and shape.

Testing.—After the water is boiling in the steam test apparatus, place the day-old pat in the apparatus, as directed in Sec. 43 of Appendix 1, and keep the pat there for 5 hrs.

Report.—State the results obtained from the test.

Questions.—Did this sample of portland cement pass the soundness test specifications?

Why should the pat have thin edges?

Is the cement sound if the bottom surface of the pat is found to be curved or warped after the conclusion of the steam test?

Does the passing of the soundness test always indicate a sound cement?

JOB 56. STANDARD TENSION TEST

Object.—To determine the tensile strength of the standard portland cement mortar.

Significance.—Tensile tests on the standard mortar give a fairly good indication of the strength qualities of a portland cement.

References.—Appendix 1 and Sec. I.

Materials.—Portland cement and standard Ottawa sand. Note the brand of the cement.

Apparatus.—Two 3-gang briquette molds, scales, graduated glass cylinder, trowel, watch, etc.

Method.—Follow the method given in Secs. 36, 37, and 50 to 61, inclusive, of Appendix 1. Make six briquettes of 1:3 mortar (1 part of cement to 3 parts of sand by weight). About 250 g. of cement and 750 g. of sand are required for six briquettes. Obtain the percentage of water from Table 1 of Appendix 1. The amount of water needed is found by multiplying the total weight of the cement and sand by the percentage given in the table.

Storage.—One day in moist air and then in water as directed in Appendix 1.

Testing.—Break three briquettes at an age of 7 days, and the remaining three at an age of 28 days. Record results.

Reports.—Tabulate the individual and average results at each age, together with the brand of cement, percentage of water, etc.

Questions.—Did this sample of portland cement pass the standard specifications for strength tests?

Does the amount of water used in making standard mortar briquettes affect their strength?

Why should the mortar be thoroughly mixed?

What is the area of the smallest cross-section of a briquette?

How would storage in air affect the strength of the briquettes?

JOB 57. FINENESS OF PORTLAND CEMENT

Object.—To determine the fineness of a sample of portland cement.

Significance.—The extremely fine powder or flour in portland cement is the important cementing element. As there are no sieves fine enough to determine satisfactorily the percentage of this flour, the fineness test only tends to indicate the soundness and strength of the cement. Usually a coarse cement will show a low mortar strength, and will often fail to pass the soundness test.

References.—Appendix 1 and Sec. I.

Materials.—Portland cement. Note the brand.

Apparatus.—Standard 200-mesh fineness sieve with cover and bottom, and scales sensitive to about 0.01 g.

Method.—Follow the method given in Appendix 1. The scales should be leveled in a place where they will not be affected by

air currents. Results should be noted to the nearest tenth of 1 per cent (nearest 0.05 g.).

Report.—State the results obtained.

Question.—Did this sample of portland cement pass the standard specifications for fineness of cement?

If the same sample of portland cement was used in Jobs 52 to 57, inclusive, and if the soundness, set, tensile strength, and fineness tests only were required, would this portland cement be considered as satisfactory for use in concrete for construction purposes?

NOTE.—Jobs 52 to 57, inclusive, include all of the tests that are usually asked for when testing a sample of portland cement. In some instances, the fineness test is omitted.

JOB 58. INSPECTION AND SAMPLING OF AGGREGATES

Object.—To inspect a source of supply for concrete aggregates, and to secure samples.

Significance.—Before beginning any large concrete job it is important that the engineer should know about the aggregates to be used, especially in regard to quantity, uniformity of supply, grading, and other qualities.

References.—Sec. I.

Method.—The following information should be obtained in regard to all stone quarries or gravel pits inspected: name of owner, locality, approximate quantity available, character of overburden or stripping, length and character of haul to the job, or to the shipping point.

Crushed Stone from Commercial Quarries.—In addition to the above information, data should be recorded concerning the crushing and screening plant, such as number and size of crushers, size and shape of screen openings, daily capacity of plant, number and size of storage bins, and sizes of crushed stone sold. When practical, samples of fresh, unweathered rock may be taken from the quarry face. Samples of crushed rock may be taken from the stock piles, bins, loading chutes, cars, or boats. It is advisable to take the samples from the cars or boats while they are being loaded—the samples being taken at different times and then well mixed to make a composite sample. If samples are taken while the cars or boats are being unloaded, samples should be obtained

from the top, middle, and bottom of each car or boat. The weight of the sample of crushed rock should be from 50 to 100 lb.

Sand and Gravel.—Very few sand and gravel deposits are uniform throughout, hence it is often necessary to take separate samples from several parts of the pit, if correct information in regard to the bank run is to be obtained. Note if any of the top soil has fallen into the pit, if there is any clay in the pit, and if there are pockets of fine or coarse material. In pits where there are screening and washing plants, the samples should be secured from the tops and the loading chutes of the bins, care being taken to obtain representative samples. If it is not practical to visit the pit or plant, samples may be taken from the top, middle, and bottom of the car or boat when unloading. Samples of bank-run gravel should be 100 lb. or more (the sample should provide at least 50 lb. of gravel after screening). Samples of gravel should contain at least 50 lb., and samples of sand at least 20 lb. A sample should be placed in a tight box or bag; and should be carefully tagged, so that it can be identified. It is a good plan to place an extra marked tag inside of the container.

Quartering Method.—All samples should be brought to the laboratory for observation and testing. If any sample is too large, it may be reduced in size by the quartering method. The sample should be first thoroughly mixed on a tight platform or floor, and then spread into a circular pile and divided into four parts or quarters. Two of the opposite quarters are shoveled away, and the process of mixing and quartering repeated until the sample is reduced to the desired size.

Report.—Write a brief report describing the crushed stone or gravel plant visited. A complete investigation would also include reports of the tests made on the samples such as sieve analyses, silt test, colorimetric test, and, when time permits, strength tests of concrete made from the aggregates.

JOB 59. UNIT WEIGHT OF CONCRETE AGGREGATES

Object.—To determine the weight per cubic foot of fine and coarse concrete aggregates.

Significance.—When designing concrete mixes by present-day methods, it is necessary to know the unit weights of the aggre-

gates, so that the proportions of the concrete mixes may be correctly computed.

References.—Appendix 2 and Sec. I.

Materials.—Room-dry samples of both fine and coarse aggregates.

Apparatus.—Tamping rods and metal measures described in Appendix 2. If these measures are not available, strong and tight wooden boxes of ½ cu. ft. and 1 cu. ft. capacity will usually prove to be satisfactory.

Method.—Follow the method given in Appendix 2. After the unit weight has been found for a room-dry sand, thoroughly dampen this sand by adding 5 per cent of water by weight, and then mix the sand and water. Then determine the unit weight of the dampened sand.

Report.—Make a tabulation showing the various materials tested, and the resulting weights per cubic foot.

Questions.—Does the dampened sand weigh more or less than the dry sand? Why?

If the proportions for a concrete mix were based on dry sand, what would be the effect on these proportions of using damp sand?

JOB 60. SIEVE ANALYSIS OF AGGREGATES

Object.—To make sieve analyses of various fine and coarse aggregates.

Significance.—As several of the methods of proportioning concrete mixes depend upon the grading of the aggregates, it is necessary first to make sieve analyses of the aggregates.

References.—Appendix 3 and Sec. I.

Materials.—Samples of different fine and coarse aggregates which are room dry.

Apparatus.—Scales which are sensitive to about ½ g., and a set of standard sieves as described in Appendix 3. These sieves are practically the same as the Tyler series of sieves, in which the opening of any sieve is double that of the next lower sieve.

Method.—Follow the method outlined in Appendix 3. If there is any doubt about a sieve not being standard, that sieve may be checked by counting the number of openings per linear

inch in both directions, and by measuring the diameter of the wire.

Computations.—For each aggregate tested, compute the percentage *passing* each sieve, and also compute the percentage *retained* on each sieve. Compute the fineness modulus of each of the aggregates.

Report.—Make a tabulation showing the sieve number or size, size of sieve opening, and, for each aggregate tested, the percentage passing each sieve, the percentage retained on each sieve, and the fineness modulus.

Questions.—Which of the fine aggregates passed the specifications for fine aggregates as given in the text? (See Sec. I, page 11.) Which of the coarse aggregates passed the specifications for coarse aggregates as given in the text? (See Sec. I, page 15.) Why should the materials be dry when sieved?

JOB 61. SIEVE ANALYSIS CURVES

Object.—To plot curves showing the sieve analyses of various fine and coarse aggregates.

Significance.—A sieve analysis curve for an aggregate enables an engineer to tell easily if that aggregate is well graded or not.

References.—Sec. I and Job 60.

Method.—On cross-section paper having, preferably, 10 divisions per lin. in., plot a sieve analysis curve for each of the aggregates tested in Job 60. Use one sheet of cross-section paper for the fine aggregates, and another sheet for the coarse aggregates. Plot percentages passing sieves to a vertical scale (ordinates), and size of sieve openings to a horizontal scale (abscissae). Consult the instructor in regard to the proper scales to use. See Appendix 3 for the sieve openings of the various sieves.

Report.—With the curve sheets, include a brief description of the aggregates tested.

Questions.—Judging by the curves, which aggregates appear to be well graded?

Which aggregates seem to be suitable for use in concrete mixes?

JOB 62. VOIDS IN FINE AND COARSE AGGREGATES

Object.—To determine the voids in samples of various fine and coarse aggregates.

Significance.—Other things being equal, a denser aggregate will make a denser and better concrete.

References.—Sec. I.

Materials.—Room-dry samples of various fine and coarse aggregates.

Apparatus.—Scales capable of weighing to 200 lb. and sensitive to 1/4 lb., a water-tight metal measuring box or strong pail having a capacity of from 1/2 to 1 cu. ft., and an iron tamping rod like that described in Appendix 2.

Method.—Weight the empty measure or pail. Fill it level full of water, and weigh it again. The weight of the water divided by 62.355 (the weight of 1 cu. ft. of water in lbs.) will give the volume of the measure in cubic feet. Be sure that the top of the measure is level when it is filled with water.

Fill the measure with an aggregate, and tamp according to the method described in Appendix 2. Weigh the measure and aggregate. Pour water slowly in the aggregate until the measure is level full. Then weigh measure, aggregate, and water. Empty and clean the measure.

Repeat the process with each of the other aggregates.

Computations.—Percentage of Voids.—The total weight of the measure, aggregate, and water, minus the weight of the measure and aggregate, gives the weight of the water in the voids. The volume of the voids in the aggregate is equal to the weight of the water in the voids divided by 62.355. The ratio of the volume of the voids to the volume of the aggregate (same as the volume of the measure) multiplied by 100 gives the percentage of voids in this aggregate.

Weight per Cubic Foot.—The weight of the dry aggregate in the measure in pounds, divided by the volume of the measure in cubic feet, gives the weight per cubic foot of the aggregate.

Approximate Specific Gravity.—The approximate specific gravity is equal to the weight of the dry aggregate in the measure divided by the difference between the volume of the aggregate (same as the volume of the measure) and the volume of the voids.

Report.—Prepare a tabulation showing all of the data taken and the results obtained. Include in the report the computation for the volume of the measure.

The following is a sample tabulation:

Material	Crushed	Gravel	Sand	Etc.
Weight of measure and aggregate in pounds.				
Weight of measure, aggregate, and water in pounds				
Weight of water in pounds.				
Volume of voids in cubic feet.				
Weight of aggregate per cubic feet. . .				
Approximate specific gravity.				

Questions.—Compare the weights per cubic foot found in this job with the weights per cubic foot found in Job 59.

Why does an aggregate composed of particles of a uniform size have a larger percentage of voids than an aggregate composed of particles of several sizes?

Why should the top of the measure or pail be level when it is filled with water?

JOB 63. SILT IN FINE AGGREGATE

Object.—To determine the amount of silt in a sample of fine aggregate.

Significance.—It is advisable to know the proportion of silt in a fine aggregate, because a comparatively large amount of silt often indicates the presence of organic impurities. A small amount of silt may ball up in a mortar, and tend to keep the cement from hardening. In some instances, however, a small amount of silt well distributed throughout a concrete mix tends to make a lean concrete more dense and waterproof.

References.—Appendix 4 and Sec. I.

Materials.—One or more samples of fine aggregate.

Apparatus.—A pan or vessel, such as is described in Appendix 4, scales, and a 500-c.c. glass graduate.

Method.—Follow the method given in Appendix 4.

An approximate method is to fill the 500-c.c. graduate up to the 200-c.c. mark with fine aggregate. Then water should be added until the 400-c.c. mark is reached. The aggregate and water should be agitated vigorously with a stiff wire or glass rod

for a time of 1 min. The graduate should then be allowed to stand until the settlement is complete. Measure the relative height of the fine aggregate and silt. Compute the percentage of silt by volume. Note that the silt does not weigh as much as the fine aggregate, hence the percentage of silt by volume is greater than the percentage of silt by weight.

A rough field method is to rub a small amount of the fine aggregate in the palm of the hand, and note if it causes a dark spot or stain on the hand. Such a stain indicates silt.

The presence of a comparatively small amount of silt may be determined by the eye, by observing if the sample of fine aggregate appears to be dirty, and if the grains seem to be coated.

Report.—Make a tabulation showing the different samples tested and the percentages of silt found.

JOB 64. COLORIMETRIC TEST OF A FINE AGGREGATE

Object.—To determine the presence of injurious organic compounds in a sample of fine aggregate.

Significance.—As a very small amount of organic matter in the fine aggregate may greatly reduce the strength and soundness of the concrete, it is important to detect the presence of organic matter in the aggregate. Silt is apt to contain organic matter, consequently it is not advisable to use a fine aggregate containing more than 3 per cent of silt as a concrete aggregate, without first testing this aggregate for the presence of injurious organic compounds, or making strength tests on a mortar made from this fine aggregate.

References.—Appendix 5 and Sec. I.

Materials.—Samples of fine aggregates.

Apparatus.—Bottles and solutions as described in Appendix 5.

Method.—Follow the method described in Appendix 5.

A very dark orange color or a dark brown color indicates that the fine aggregate has an appreciable amount of injurious organic matter. A light yellow or white color indicates that there is very little injurious organic matter present. In general, solutions darker than the standard solution indicate the presence of injurious organic matter. In doubtful cases strength tests of a mortar or concrete (made with the aggregate in question) should be made before arriving at a final decision.

Report.—Report on all fine aggregates tested giving the color of the liquid in the bottle in each case. State which aggregates are acceptable for use in concrete mixes.

JOB 65. BULKING EFFECT OF WATER IN SAND

Object.—To observe the bulking effect of water in sand.

Significance.—Comparatively small percentages of water (from 4 to 8 per cent) added to a dry sand will cause the sand to increase in volume. A knowledge of this bulking effect is essential when designing concrete mixes in which wet sand is used.

References.—Sec. I.

Materials.—A sample of room-dry sand, or, preferably, a sample of sand dried to a constant weight.

Apparatus.—Scales, 500-c.c. glass graduate, glass or metal rod for tamping.

Method.—1. Weigh out sufficient drys and to fill the 500-c.c. graduate about half full. Place the sand in the graduate in about three equal layers, tamping each layer as described in Appendix 2. Record the volume of the sand in the graduate.

2. Weigh out an equal amount of dry sand as before, add 2 per cent of water by weight, mix sand and water thoroughly, tamp in graduate as before, and record the volume.

3. Repeat the process using 4, 6, 8, and 10 per cent of water. Record the results.

4. Make one trial with enough water just to flood or inundate the sand. Record percentage of water used, and the resultant volume.

If sufficient graduates are available, each mixture of sand and water can be left in its respective graduate. Placing these graduates in order in a row will illustrate the bulking effect of water very nicely.

Report.—Make a tabulation showing the percentages of water added and the percentages of increase in volume (bulking) of the sand.

Questions.—What percentage of water appeared to give the maximum bulking effect for this particular sand?

How did the volume of the inundated sand compare with the volume of the dry sand?

JOB 66. TENSILE STRENGTH OF CEMENT MORTARS MADE WITH DIFFERENT SANDS

Object.—To compare the tensile strength of mortars made with different sands.

Significance.—It is often advisable to make strength tests on mortars made from sands to determine if the sands are suitable for mortars and concretes.

References.—Sec. I.

Materials.—Portland cement and samples of fine, coarse, and well-graded sands. Note brand of cement.

Apparatus.—Scales, three 3-gang briquette molds, glass graduate, watch, trowel, etc.

Method.—Make three briquettes using each kind of sand. Follow method given in Appendix 1 for mixing and molding briquettes. All mixes are 1:3 by weight. About 125 g. of cement and 375 g. of sand are required for three briquettes. Knowing the percentage of water required for normal consistency of the cement, obtain the percentage of water for the 1:3 mortar from Table 1 of Appendix 1. It may be necessary slightly to vary the values given in the table for the different sands in order to get a workable mix.

Storage.—One day in moist air and then in water.

Testing.—Break all briquettes at an age of 28 days. If time does not permit, the briquettes may be broken at 7 or 14 days. Weigh each set of briquettes before testing.

Report.—Tabulate the individual and average results for each sand together with the brand of cement, kind of sand, percentage of water, weights of briquettes, etc. Include in this tabulation the results of the 28-day tensile test made on the 1:3 mortar of standard Ottawa sand. If available, include the weights per cubic foot of the sands.

Questions.—Which sand made the strongest mortar? Why?

Which sand made the heaviest (or densest) briquettes?

Were the heaviest briquettes the strongest?

JOB 67. TENSILE STRENGTH OF CEMENT MORTARS OF DIFFERENT PROPORTIONS

Object.—To determine the effect of varying the amount of the cement on the tensile strength of the mortar.

Significance.—Other things being equal, the greater the proportion of cement, the greater the strength of the mortar.

References.—Sec. I.

Materials.—Portland cement and a fairly well-graded sand. Note the brand of cement.

Apparatus.—Scales, three 3-gang briquette molds, glass graduate, watch, trowel, etc.

Method.—Follow the method of mixing and molding given in Appendix 1, and make nine briquettes as follows:

Three briquettes, 1:1 mix, using 250 g. of cement and 250 g. of sand.

Three briquettes, 1:3 mix, using 125 g. of cement and 375 g. of sand.

Three briquettes, 1:5 mix, using 80 g. of cement and 400 g. of sand.

Compute the percentage of water required for each mix by the formula:

$$\text{Percentage of water} = \frac{2P}{3n + 3} + 6.5$$

Where P = percentage of water for normal consistency of cement, and

n = number of parts of sand to one of cement.

The percentage of water is based on the combined weight of the cement and the sand. For example, if the cement requires 24 per cent of water for normal consistency, the percentage of water for a 1:3 mortar is found by substituting in the formula as follows:

Percentage of water for a 1:3 mortar =

$$\frac{2 \times 24}{3 \times 3 + 3} + 6.5 = \frac{48}{12} + 6.5 = 10.5 \text{ per cent.}$$

If there were 500 g. of cement and sand, the amount of water needed would be 500 × 10.5 per cent or 52.5 c.c. (or grams).

Storage.—One day in moist air and then in water.

Testing.—Break all briquettes at an age of 28 days.

Report.—Tabulate the individual and average results for each mix, together with the brand of cement, kind of sand, proportion of mix, percentage of water, etc.

Question.—What conclusions may be drawn from the results of this test?

JOB 68. CONSISTENCY OF PORTLAND CEMENT CONCRETE

Object.—To determine the consistency of a mix of portland cement concrete by means of the "slump" test.

Significance.—The best results are obtained in concrete work when the least amount of mixing water is used that will give a concrete of just workable consistency for the job in question. Concrete that is to be used in floors and thin walls requires a little more mixing water than if it were to be used in heavy foundations or massive concrete work.

References.—Appendices 7 and 8 and Jobs 9 to 13 inclusive.

Materials.—Portland cement and room-dry fine and coarse aggregates. The maximum size of the coarse aggregate should not be more than $1\frac{1}{2}$ in. Note the brand of the cement and the kinds of the aggregates.

Apparatus.—Measuring boxes, scales, water-tight mixing platform, shovels, trowels, pail, watch, and slump test apparatus as described in Appendix 7. If a concrete mixer is used, the mixing platform is not needed.

Method.—Follow methods given in Appendix 7 for the slump test, and in Appendix 8 for mixing a batch of concrete by hand. In laboratory work, the amount of water is frequently given as a percentage of the weight of the cement or of the total weight of the dry materials. On the job, the amount of mixing water is usually given as the number of gallons of water per sack of cement. Thus the water may be either weighed or measured. Either way is satisfactory, provided the scales and measures are accurate.

If either, or both, of the aggregates are wet, the amount of water present in the aggregates must be determined and allowance made. The amount of water in any aggregate may be found by weighing a sample of the aggregate, drying this sample to constant weight, and weighing again. The difference between the two weights gives the amount of water that was present. If the aggregates are thoroughly room dry, the amount of water in the aggregate is probably quite small and may be neglected.

Make a batch of 1:2:4 concrete by volume, using just enough water to give a mix of workable consistency. Perform the slump test. Record the proportions of the mix, amount of water used, and observed slump in inches.

Report.—Include in the report the brand of cement, kinds of aggregates, proportions of mix, amount of water used, slump, and any other data of importance.

Questions.—How many gallons of water per sack of cement were required?

What is the water cement ratio (ratio of volume of water in cubic feet to volume of cement in cubic feet in this mix)?

If the weights per cubic foot of the aggregates are available, what would be the proportions of the mix by weight? Assume that 1 cu. ft. of cement weighs 94 lb.

What should be the maximum slump permitted for:

1. Mass concrete?
2. Reinforced concrete of
    a. thin, vertical sections and columns?
    b. heavy sections?
    c. thin, confined horizontal sections?
3. Mortars for floor finish?

JOB 69. PROPORTIONING CONCRETE BY ARBITRARY PROPORTIONS

Object.—To proportion concrete mixes by arbitrary proportions.

Significance.—Proportioning concrete mixes by volume by arbitrary proportions was (and still is in many localities) the generally accepted method of proportioning. At the present time this method is used for most small jobs, but is being superceded by more scientific methods for the large jobs.

References.—Appendices 7 and 8; Sec. I; Jobs 1, 2, and 10 to 13, inclusive.

Materials.—Portland cement and room-dry fine and coarse aggregates. The maximum size of the coarse aggregate should not exceed $1\frac{1}{2}$ in. Note the brand of the cement and the kinds of aggregates.

Apparatus.—Measuring boxes, scales, mixing platform, shovels, trowels, and six (or nine) cylinder molds 6 in. in diameter and 12 in. high, with machined metal base plates and capping plates. A hydraulic compression testing machine (or a universal testing machine), scales, calipers, and ruler.

Method.—Quantities.—Using Fuller's rule (Job 12) compute quantities of cement, fine and coarse aggregates to make two (or three) cylinders of concrete for each of the following mixes by volume: 1:2:4, 1:3:6, and 1:4:8.

Consistency.—Use enough water in each mix to give a consistency having a slump of 6 in. Note amount of water required in each case.

NOTE.—If a compression testing machine and cylinder molds are not available, this job may be discontinued at this point.

Mixing and Molding.—Mix and mold each set of cylinders according to the method given in Appendix 8. The cylinder molds and base plates should be thoroughly oiled with a heavy oil before the concrete is placed in them. The capping must be carefully done if consistent results are to be obtained.

Storage.—Store cylinders as directed in Appendix 8.

Testing.—When the cylinders are 28 days old, weigh them, measure their diameter and height, and test them as directed in Appendix 8. Note the maximum (ultimate) load applied to each cylinder, and the manner of failure. For each cylinder, compute the weight per cubic foot, cross-sectional area, in square inches, and the unit ultimate compressive strength.

Report.—Tabulate all data and results including the proportions of each mix, water-cement ratios, unit weights of materials (if available), weights and dimensions of the cylinders, maximum loads applied, unit strengths, etc.

Questions.—If the unit weights of the aggregates are available, what are the proportions of the different mixes by weight?

How many gallons of water per sack of cement were used in each mix?

Did there appear to be any relation between the unit ultimate compressive strength, and the weight per cubic foot of cylinders of the same mix?

How do the unit compressive strengths obtained for the different mixes compare with the values given by Curve *A* of Fig. 3, page 18?

JOB 70. PROPORTIONING CONCRETE BY THE USE OF THE TABLES OF THE 1924 JOINT COMMITTEE REPORT

Object.—To proportion a concrete mix, having a slump of 6 in., to give a compressive strength of 2000 lb. per sq. in. at the

age of 28 days by the use of the tables given in the 1924 *Report* of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete. (See Appendix 6.)

Significance.—These tables have been prepared to give suitable proportions of portland cement, fine and coarse aggregates to obtain a concrete of desired compressive strength at an age of 28 days, when control tests (28-day compression tests on cylinders) are not to be made.

References.—Appendices 2, 3, 6, 7, and 8; Sec. I; and Jobs 1, 6, and 10 to 13, inclusive.

Materials.—Portland cement and room-dry fine and coarse aggregates. The maximum size of the coarse aggregate should preferably be $1\frac{1}{2}$ in. Note the brand of the cement and the kinds of the aggregates.

Apparatus.—Scales, measuring boxes, and tamping rods, as in Appendix 2 and Job 59; scales and sieves, as in Appendix 3 and Job 60; slump test apparatus, as in Appendix 7; mixing platform, scales, shovels, trowels, and two or three 6- × 12-in. cylinder molds, as described in Appendix 8. If sufficient cylinder molds are available, it is better to make the cylinders in sets of three, instead of sets of two, as given in this and the following jobs.

Method.—Determine the weight per cubic foot of each aggregate (if not previously determined) as in Job 59.

Make sieve analyses of the aggregates as in Job 60.

From the tables in Appendix 6, determine the required mix, having a slump of 6 in., to give a compressive strength of 2000 lb. per sq. in. at an age of 28 days, paying particular attention to the rules given in Appendix 6 for determining the limiting sizes of the aggregates.

Compute the quantities of materials required to make two 6- × 12-in. cylinders.

Mix the concrete for these two cylinders, using enough water to give a slump of 6 in. when tested as directed in Appendix 7.

Make the cylinders according to the directions given in Appendix 8.

Store the cylinders as directed in Appendix 8.

Weigh, measure, and test cylinders at an age of 28 days according to the methods given in Appendix 8. Observe the maximum

(ultimate) load applied, and the manner of failure for each cylinder.

If the unit weights and sieve analyses of these aggregates have been determined in preceding jobs, the values found may be used for this job.

Report.—Compute the unit ultimate compressive strengths of the cylinders tested. Compute the water-cement ratio, and the number of gallons of water used per sack of cement.

Questions.—Did the proportions selected give a greater or less unit ultimate compressive strength than 2000 lb. per sq. in.?

How does the average unit ultimate compressive strength obtained in this job compare with the unit strength given by Curve *A* of Fig. 3, page 18?

JOB 71. PROPORTIONING CONCRETE BY THE WATER-CEMENT RATIO AND SLUMP TEST

Object.—To proportion a mix of concrete by the water-cement ratio and the slump test to obtain a mix having a slump of 6 in. and a unit ultimate compressive strength of 2000 lb. per sq. in. at an age of 28 days.

Significance.—The water-cement ratio is the important element governing the compressive strength of a concrete mix. The strength may be said to vary inversely as the number of gallons of mixing water per sack of cement, irrespective of the amount of aggregate present, provided the concrete mix has a workable consistency. This consistency of the mix may be controlled by the slump test.

References.—Appendices 2, 7, and 8, Sec. I; Jobs 1, 7, and 10 to 13, inclusive.

Materials.—Portland cement and room-dry fine and coarse aggregates. The maximum size of the coarse aggregate should not be more than 1½ in. Note the brand of cement and the kinds of aggregates.

Apparatus.—Slump test apparatus described in Appendix 7 and scales, measuring boxes, mixing platform, shovels, trowels, two 6- × 12-in. cylinder molds, etc. for making concrete cylinders. If unit weights are to be found, the apparatus described in Appendix 2 will be needed.

Method.—Determine the weights per cubic foot of the fine and coarse aggregates by the method in Appendix 2, if these weights are not available from previous jobs.

Thoroughly mix the fine and coarse aggregates according to one of the following proportions. (*a*) If the coarse aggregate appears to be uniformly graded and has a suitable proportion of the smaller sizes of particles, use a 1:2 mix by volume (1 part of fine aggregate to 2 parts of coarse aggregate); or (*b*) If the coarse aggregate does not appear to be uniformly graded, or if a suitable proportion of the smaller sizes of particles are not present, use a 2:3 mix by volume (2 parts of fine aggregate to 3 parts of coarse aggregate).

Obtain the weight per cubic foot of the mixed aggregate by the method given in Appendix 2.

From Curve *A* of Fig. 3, page 18, $7\frac{1}{2}$ gal. of water per sack of cement should give a concrete having a unit ultimate compressive strength of 2000 lb. per sq. in. at an age of 28 days. Note the water-cement ratio.

On a water-tight mixing platform, mix thoroughly a half sack of cement (47 lb.), $3\frac{3}{4}$ gal. of water, and enough of the mixed aggregate, so that the resulting concrete will have a slump of 6 in. when tested by the slump test. If care is taken in the adding of the mixed aggregate and water to the cement it is possible to obtain a mixture having a slump of 6 in. without much trouble.

NOTE.—In laboratory work, it is often preferable to weigh the materials. Cement weighs 94 lb. per cu. ft., water weighs 62.355 lb. per cu. ft. or 8.35 lb. per gal., while the unit weights of the fine, coarse, and mixed aggregates may be found by the methods given in Appendix 2.

Mold two (or three, if molds are available) 6- × 12-in. cylinders by the method given in Appendix 8.

Store the cylinders as directed in Appendix 8.

Weigh, measure, and test the cylinders at an age of 28 days. Note the maximum (ultimate) load applied, and manner of failure of each cylinder.

Compute the ultimate unit compressive strength of each cylinder.

Report.—Include in the report all essential data, computations, and results.

Questions. What were the proportions by volume of the cement to the mixed aggregate? What were the proportions by weight?

What were the proportions by volume of cement, fine aggregate, and coarse aggregate? What were the corresponding proportions by weight?

Was the average unit ultimate compressive strength more or less than 2000 lb. per sq. in.?

How did the water-cement ratio in this job compare with the ratio of the preceding job?

How did the proportions of the mix in this job compare with the proportions in the preceding job?

How did the unit ultimate compressive strength of the concrete in this job compare with the strength obtained in the preceding job?

Were the same aggregates used in both jobs?

How did the unit ultimate compressive strength obtained in this job compare with the value given by Curve *A* of Fig. 3?

JOB 72. PROPORTIONING CONCRETE BY THE WATER-CEMENT RATIO, SLUMP, AND FINENESS MODULUS OF AGGREGATE

Object.—To proportion a mix of concrete by the water-cement ratio, slump test, and fineness modulus of the aggregate, to obtain a mix having a slump of 6 to 7 in., and a unit ultimate compressive strength of 2000 lb. per sq. in. at an age of 28 days.

Significance.—The compressive strength of the mix is controlled by the water-cement ratio, the workability by the slump, and the economy by the grading of the mixed aggregate, as evidenced by the fineness modulus.

References.—Appendices 2, 3, 7, and 8; Sec. I; Jobs 1 and 8 to 13, inclusive.

Materials.—Portland cement and fine and coarse aggregates. The maximum size of the coarse aggregate should not be more than 1½ in. Note the brand of cement and the kinds of aggregates.

Apparatus.—Apparatus for sieve analyses as described in Appendix 3, apparatus for determining unit weights as described in Appendix 2, slump test apparatus as described in Appendix 7,

and scales, measuring boxes, mixing platform, shovels, trowels, two 6- × 12-in. cylinder molds, etc., for making concrete cylinders.

Method.—If there is any doubt in regard to the quality of the fine aggregate, it should be tested for silt and organic impurities as described in Appendices 4 and 5.

The relation between the compressive strength and water-cement ratio shown by Curve *A* of Fig. 3, page 18, will be assumed to apply on this job, because working conditions in the laboratory should be such that the proportioning can be accurately controlled.

The detailed method of procedure given in Jobs 8 and 9 should be followed.

The tests for slump and harshness should not be omitted.

Using the proportions determined, compute quantities of materials required for two 6- × 12-in. cylinders.

Mix the concrete and make the cylinders as directed in Appendix 8.

Store the cylinders as directed in Appendix 8.

Weigh, measure, and test the cylinders at an age of 28 days, according to the methods given in Appendix 8. Observe the maximum (ultimate) load applied and the manner of failure for each cylinder. Compute the ultimate unit strength of each cylinder.

Report.—Write a complete report for this job including all data and results.

Questions.—Did the proportions selected give a greater or less ultimate compressive strength than 2000 lb. per sq. in.?

Prepare a simple tabulation showing a comparison of the results obtained in Jobs, 70, 71, and 72 in regard to proportions, water-cement ratio, slump, and strength. Were the same aggregates used in all three jobs?

JOB 73. EFFECT OF VARYING THE AMOUNT OF MIXING WATER IN A GIVEN MIX

Object.—To determine the effect of varying the amount of the mixing water on the consistency and compressive strength of a concrete mix.

Significance.—It is advisable to use the smallest amount of mixing water that will give a workable mix, because the strength of a concrete mix varies inversely as the water-cement ratio.

Increasing the quantity of mixing water in a mix of given proportions will increase the workability or slump, and will also decrease the compressive strength.

References.—Appendices 7 and 8; Sec. I; Jobs 1 and 10 to 13, inclusive.

Materials.—Portland cement and room-dry fine and coarse aggregates. The maximum size of the coarse aggregate should not be more than 1½ in. Note the brand of the cement and the kinds of aggregates.

Apparatus.—Scales, measuring boxes, mixing platform, shovels, trowels, eight 6- × 12-in. cylinder molds, and the slump test apparatus described in Appendix 7.

Method.—Compute quantities of cement, fine and coarse aggregates, to make two cylinders using a 1:2:4 mix by volume.

1. Make two cylinders using enough water to give a slump of about 1 in.

2. Make two cylinders using 10 per cent more water than in (1). Observe the slump.

3. Make two cylinders using 25 per cent more water than in (1). Observe the slump.

4. Make two cylinders using 50 per cent more water than in (1). Observe the slump.

Observe how readily the water flushes to the surface when tamping the cylinders in the molds. Record the amount of water used in each batch.

Follow the methods given in Appendices 7 and 8 when mixing, testing for slump, and molding the cylinders.

Store the cylinders as directed in Appendix 8.

Weigh, measure, and test all cylinders at an age of 28 days, observing the maximum (ultimate) load and manner of failure for each cylinder.

Report.—Compute the water-cement ratio for each of the four mixes, and the unit ultimate compressive strength of each cylinder. Prepare a simple tabulation showing all essential data and results.

Questions.—Which consistency produced a concrete of the greatest strength?

Was there any general relation between the weights of the individual cylinders and their compressive strengths?

Was there any general relation between the water-cement ratios of the different batches and their compressive strengths?

How did the unit compressive strengths obtained compare with the values given by Curve A of Fig. 3, page 18?

How did the slumps obtained compare with the general statement made in regard to quantity of mixing water and slump in Job. 10, page 47?

JOB 74. EFFECT OF VARYING THE FINENESS MODULUS OF THE AGGREGATE ON THE ECONOMY OF THE MIX

Object.—To determine the effect of varying the fineness modulus of the mixed aggregate on the economy of the mix.

Significance.—The amount of mixed aggregate, which may be added to a given quantity of cement and water to produce a mix with a certain slump, increases as the fineness modulus increases (and vice versa), as long as the mix is not too harsh. In other words, for a mix of a given strength and workability, the coarser the mixed aggregate, the greater the quantity or proportion of this mixed aggregate which may be used, and the greater the economy of the mix.

References.—Appendices 2, 3, 7, 8; Sec. I; Jobs 1 and 8 to 13, inclusive.

Materials.—Portland cement and dry fine and coarse aggregates. The maximum size of the coarse aggregate should not be more than $1\frac{1}{2}$ in. Note brand of cement and kinds of aggregate.

Apparatus.—Apparatus for unit weights of aggregates, sieve analysis, and slump test, as described in Appendices 2, 3, and 7, respectively, and scales, measuring boxes, mixing platform, shovels, trowels, six 6- × 12-in. cylinder molds, etc., for making concrete cylinders.

Method.—Determine unit weights of the dry fine and coarse aggregates according to method given in Appendix 2.

Make sieve analyses of the fine and coarse aggregates (according to the method given in Appendix 3), and compute their fineness moduli.

Combine the fine and coarse aggregates in different proportions to give three mixed aggregates having fineness moduli of about 5.2, 5.9, and 6.6, respectively.

Using a water-cement ratio of 1 (7.50 gal. per sack of cement) and a slump of from 6 to 7 in., make three batches as follows:

1. Using the mixed aggregate with a fineness modulus of about 5.2. Note the proportion of mixed aggregate used, and then mold two cylinders.

2. Using the mixed aggregate with a fineness modulus of about 5.9. Note the proportion of mixed aggregate used, and then mold two cylinders.

3. Using the mixed aggregate with a fineness modulus of about 6.6. Note the proportion of mixed aggregate used, and then mold two cylinders.

Follow the methods given in Appendices 7 and 8 when testing for slump and molding the cylinders.

Store the cylinders as directed in Appendix 8.

Weigh, measure, and test all cylinders at an age of 28 days, observing the maximum (ultimate) load and manner of failure for each cylinder. Compute the unit ultimate compressive strength of each cylinder. If the work has been carefully done, the individual strengths of the cylinders should be about the same.

Report.—Prepare a simple tabulation showing all essential data and results.

Questions.—Which value of the fineness modulus of mixed aggregate gave the most economical mix?

What general conclusion may be drawn from the results of this job, in regard to the relation between the fineness modulus and the quantity of the mixed aggregate which may be added to a definite amount of cement and water to produce a certain slump?

How did the unit compressive strengths found in this job compare with the value given by Curve *A* of Fig. 3, page 18?

Did the unit compressive strength of any cylinder (or cylinders) vary greatly from the average of all? If so, was there any apparent reason for this variation?

JOB 75. EFFECT OF VARYING THE FINENESS MODULUS OF THE AGGREGATE UPON THE SLUMP, AND UPON THE WATER-CEMENT RATIO REQUIRED FOR A GIVEN SLUMP

Object.—To determine the effect of varying the fineness modulus of the mixed aggregate: (*a*) upon the slump with the proportions of cement, water, and mixed aggregate remaining

constant; and (*b*) upon the water-cement ratio required with the slump and proportions of cement and mixed aggregate remaining constant.

Significance.—With the proportions of cement, water, and mixed aggregate remaining the same, an increase in the fineness modulus (coarseness) of the mixed aggregate will increase the slump of the mix. With the slump and proportions of cement and mixed aggregate remaining the same, an increase in the fineness modulus (coarseness) of the mixed aggregate will decrease the amount of mixing water required to produce the given slump, and thus decrease the water-cement ratio and increase the strength of the mix, as long as the mix is not harsh.

References.—Appendices 2, 3, 7, 8; Sec. I; Jobs 1 and 8 to 13, inclusive.

Materials.—Portland cement and dry fine and coarse aggregates. The maximum size of the coarse aggregate should not be more than $1\frac{1}{2}$ in. Note brand of cement and kind of aggregates.

Apparatus.—Apparatus for unit weights, sieve analysis, and slump test as described in Appendices 2, 3 and 7, respectively, and scales, measuring boxes, mixing platform, shovels, trowels, six 6- × 12-in. cylinder molds, etc., for mixing concrete and making cylinders.

Method.—Determine unit weights of the fine and coarse aggregates according to the method given in Appendix 2.

Make sieve analyses (according to the method given in Appendix 3) of the fine and coarse aggregates, and compute their fineness moduli.

Combine the fine and coarse aggregates in different proportions to give three mixed aggregates having fineness moduli of about 5.2, 5.9 and 6.6, respectively.

1. With a water-cement ratio of 1 (7.50 gal. of water per sack of cement), mix a batch of concrete, using enough of the mixed aggregate having a fineness modulus of about 5.2 to give a slump of about 3 in. Note the proportion of this mixed aggregate used and the resulting slump of the mix.

2. With the same water-cement ratio and the same proportions of mixed aggregate as in (1) mix a batch of concrete using the mixed aggregate, having a fineness modulus of about 5.9. Note the slump of the mix.

3. With the same water-cement ratio and the same proportion of mixed aggregate as in (1), mix a batch of concrete using the mixed aggregate having a fineness modulus of about 6.6. Note the slump of the mix.

4. With a water-cement ratio of 1 (7.50 gal. of water per sack of cement), mix a batch of concrete, using enough of the mixed aggregate having a fineness modulus of about 5.2 to give a slump of about 7 in. Note proportions of this mixed aggregate used. Make two cylinders from this batch of concrete.

5. With the same proportions of cement and mixed aggregate as in (4) mix a batch of concrete, using the mixed aggregate having a fineness modulus of about 5.9 and just enough mixing water to give a slump of about 7 in. Note amount of mixing water used, and compute the water-cement ratio. Make two cylinders from this batch of concrete.

6. With the same proportions of cement and mixed aggregate as in (4) mix a batch of concrete, using the mixed aggregate having a fineness modulus of about 6.6 and just enough mixing water to give a slump of about 7 in. Note amount of mixing water used and compute the water-cement ratio. Make two cylinders from this batch of concrete.

Follow the methods given in Appendices 7 and 8 when testing for slump and molding the cylinders.

Store the cylinders as directed in Appendix 8.

Weigh, measure, and test all cylinders at an age of 28 days, observing the maximum (ultimate) load and manner of failure of each cylinder. Compute the unit ultimate compressive strength of each cylinder.

Report.—Prepare a simple tabulation showing all essential data and results obtained in regard to the effect of varying the fineness modulus upon the slump.

Prepare a similar tabulation, showing all essential data and results obtained in regard to the effect of varying the fineness modulus upon the amount of mixing water required for a given slump.

Questions.—From the results obtained, what general conclusions may be drawn in regard to the effect of varying the fineness modulus upon the slump when the water-cement ratio and proportion of mixed aggregate remain constant?

From the results obtained, what general conclusions may be drawn in regard to the effect of varying the fineness modulus upon the amount of mixing water required for producing a given slump, when the proportions of cement and mixed aggregate remain constant? Upon the water-cement ratio of a mix when the slump and proportions of cement and mixed aggregate remain constant? Upon the strength of a mix when the slump and proportions of cement and mixed aggregates remain constant?

JOB 76. EFFECT OF AGE ON THE COMPRESSIVE STRENGTH OF CONCRETE

Object.—To observe the effect of age on the compressive strength of concrete.

Significance.—In general, the compressive strength of concrete increases with age, the rate of increase in strength becoming less as the concrete becomes older.

References.—Appendices 7 and 8; Sec. I; Jobs 1 and 10 to 13, inclusive.

Materials.—Portland cement and room-dry fine and coarse aggregates. The maximum size of the coarse aggregate should not be more than $1\frac{1}{2}$ in. Note the brand of the cement and the kinds of the aggregates.

Apparatus.—Scales, measuring boxes, mixing platform, shovels, trowels, six 6- × 12-in. cylinder molds, and slump test apparatus as described in Appendix 7.

Method.—Compute the quantities of materials required for the six cylinders using a 1:2:4 mix by volume.

Mix the concrete using enough water to give a slump of about 6 in., as shown by the slump test. Compute the water cement ratio. Follow methods given in Appendix 8 for making and molding the cylinders.

Store the cylinders as directed in Appendix 8.

Weigh, measure, and test two cylinders at an age of 7 days, another two at an age of 28 days, and the remaining two at an age of 60 or 90 days, as time permits. Note the maximum (ultimate) load applied to each cylinder, and compute its unit ultimate compression strength.

Report.—Tabulate all essential data and results.

Questions. What general conclusions may be drawn regarding the effect of age on the compressive strength of concrete?

Compare the unit compressive strength at 28 days with the value given by Curve *A* of Fig. 3, page 18.

Using the average unit compressive strength at 7 days, find the probable unit compressive strength at 28 days from the curve of Fig. 5, page 21.

How does the probable unit compressive strength at 28 days, found from the curve, compare with the unit compressive strength found in the 28-day tests?

JOB 77. TESTS REQUIRED FOR CONCRETE MATERIALS

This article is intended to be a general summary of the tests required of concrete materials. References are given to the jobs in which more complete information may be obtained.

Before the concrete materials to be used on any job are tested, representative samples must be secured of each of the materials. Appendix 1, Sec. I, and Jobs 52 and 58 contain information in regard to the sampling of materials.

For information regarding tests on portland cement, refer to Sec. I, Jobs 52 to 57, inclusive, and Appendix 1. The tests usually required of portland cement are: normal consistency of neat cement paste; soundness; time of set; tensile strength of standard sand mortar; and fineness. Tests rarely called for are: specific gravity; and chemical tests.

On small and medium-sized jobs, most of the fine aggregate is used without any preliminary testing, though tests are being required more frequently on sands used for concrete on large jobs. Appendices 2 to 5 inclusive, Sec. I, and Jobs 58 to 65, inclusive, give considerable information in regard to the testing of fine aggregates. Tests that may be required are: weight per cubic foot; sieve analysis; silt; colorimetric test; bulking effect of water; percentage of moisture present; percentage of voids; and tension and compression tests of mortars made with a portland cement of known quality, and the fine aggregate in question.

Coarse aggregates are rarely tested when used on comparatively small and unimportant concrete work. On many large jobs, the coarse aggregates are now tested to determine their suitability for concrete work. Further information relating to

the testing of coarse aggregates is given in Appendices 2 and 3, Sec. I, and in Jobs 58 to 65, inclusive. Tests that are frequently asked for are: weight per cubic foot; sieve analysis; silt; percentage of voids; and compression tests on concretes made with portland cement and fine aggregate of known quality, and the coarse aggregate in question.

Water is rarely tested before using it for concrete purposes. If the water is suitable for drinking purposes, it is usually suitable for concrete mixes. Water that is not suitable for drinking purposes should be regarded with suspicion. Section I gives further information.

Compression and tension tests are the ones usually required on portland cement mortars. Section I and Jobs 66 and 67 give information regarding the strength of mortars.

Appendices 7, 8, and 9, Sec. I, and Jobs 1 to 14, inclusive, and 68 to 76, inclusive, give much information in regard to the proportioning, mixing, molding, curing, and testing of concrete. Slump tests for consistency and compression tests are often required, while cross-bending and yield tests are rarely called for.

Compression and absorption tests are usually required of concrete block and brick. Cross-bending tests are sometimes asked for. References for the requirements of concrete block and brick are Appendices 11 and 12, and Job 31.

Questions.—Name the tests commonly required for each of the following: portland cement, sand, crushed stone or gravel, portland cement mortars, portland cement concretes, and concrete brick and block.

JOB 78. TESTING MACHINES USED IN TESTING CONCRETE AND CONCRETE MATERIALS

Testing machines (other than the Vicat apparatus, Gillmore needles, briquette molds, etc., described in Appendix 1), used for testing portland cement and cement mortars, are briquette testing machines for tensile tests, and hydraulic compression or universal testing machines for compression tests.

In the automatic briquette testing machine, the load is applied at a uniform rate (usually 600 lb. per min.) by shot flowing from a hanging bucket or receptacle in the machine. There are many devices for regulating the flow of shot and applying the load.

The machine is so constructed that the flow of shot is automatically stopped when the briquette breaks. The operation of the

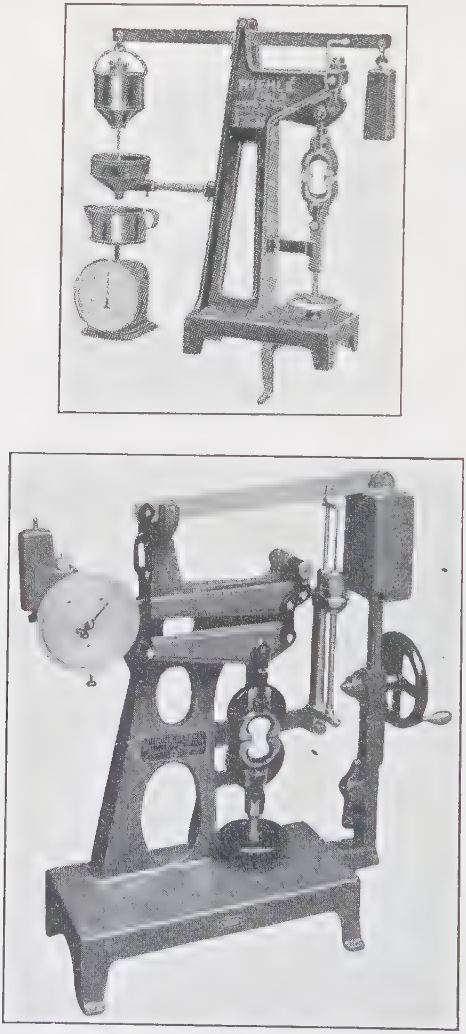


FIG. 77.—Automatic cement briquette testing machines.

ordinary shot machine is as follows: See that beam balances with no load, place briquette in grips, tighten grips, start flow of shot,

keep beam balanced by turning hand crank, observe and record breaking load when briquette breaks. The capacities of the automatic briquette testing machines are usually 1000 lb., though 2000-lb. machines may be purchased.

A hydraulic compression machine of from 50,000- to 200,000-lb. capacity is useful for crushing mortar and concrete specimens where the ultimate strength is desired. Most of these machines

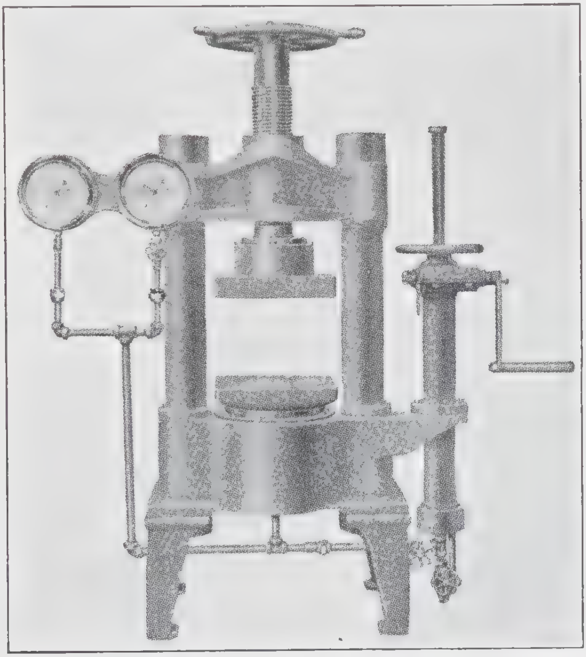


Fig. 78.—Hydraulic compression testing machine.

consist of a strong frame with an oil cylinder, in which oil is pumped by a hand or power pump. In operating the machine, the specimen is placed squarely in the center of the lower bearing block, the upper bearing block is brought down to the top of the specimen and tightened by means of the hand wheel at the top of the machine, the load is applied by pumping oil into the cylinder, and the load (represented by oil pressure) is read by means of the oil-pressure gages. One of the bearing blocks (preferably the upper) should be a spherical block. When the specimen is

accurately centered in the machine, the spherical joint of this block helps to correct any slight lack of parallelism in the upper and lower surfaces of the specimen.

The most common type of testing machine is the universal testing machine. The essential parts of this machine are a weighing platform for supporting the specimen, levers, a scale

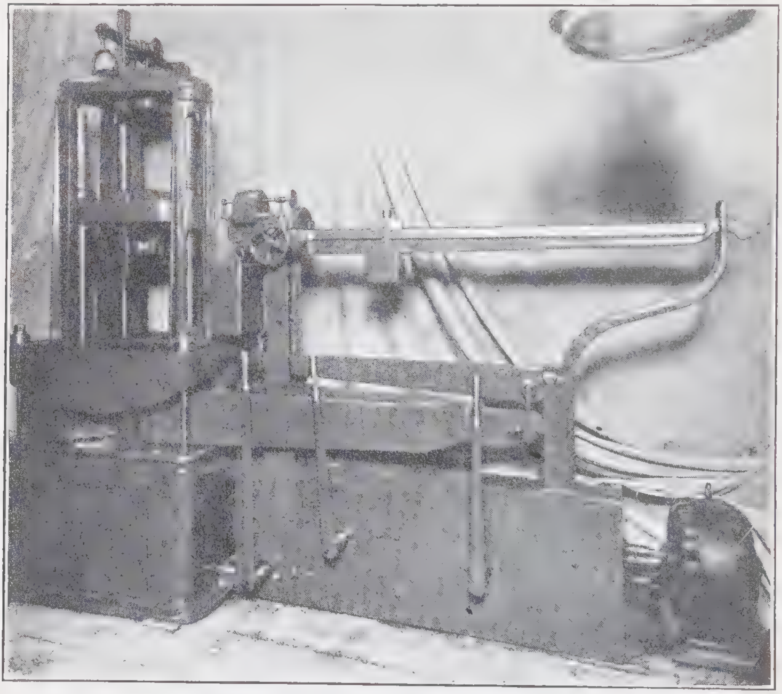


Fig. 79.—Universal testing machine.

beam for measuring the load, and a pulling head connected to a gear system for applying the load. The weighing platform, levers, and scale beam are somewhat like those of an ordinary weighing scale. The load is applied by means of a pulling head and screws (usually two, three, or four in number) operated by a set of gears attached to a motor or line belt. This pulling head can be operated at several different speeds. The load is always applied by a downward movement of the pulling head. Usual

capacities of universal machines used in laboratories vary from 50,000 to 200,000 lb.

In making compression tests (as of mortar or concrete specimens), a bearing plate is attached to the under side of the pulling head, and another bearing plate placed in the center of the weighing table. One of these bearing plates should have a spherical joint to care for a possible slight lack of parallelism in the upper and lower surfaces of the specimen. The specimen is placed on the lower bearing block, so that the vertical axis of the specimen and block are in the same line. The pulling head is then lowered until it is just in contact with the top of the specimen. The load is applied by moving the pulling head slowly downward, and the amount of the load is measured by moving the poise on the scale beam and keeping this beam balanced.

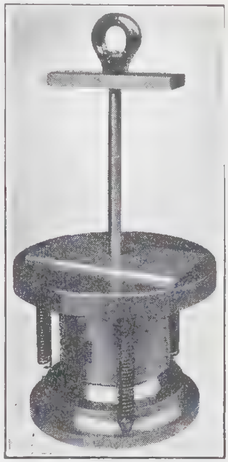


FIG. 80.—Spherical bearing block.

A spherical bearing block is a necessary adjunct for making compression tests. The spherical joint permits the part of the bearing block in contact with the specimen to move and adjust itself to the test conditions.

Questions.—Briefly describe the operation of an automatic cement briquette testing machine shown in the figure accompanying this job.

Why should a spherical bearing block be used in a compression test?

Briefly describe the operation of a universal testing machine when making a compression test.

SECTION VI

FIELD WORK

INSPECTION OF CONCRETE WORK

It is the duty of the inspector on concrete work to see that the contractor provides the materials called for, and does the work in accordance with the specifications and plans. Any deviations from the specifications and plans should be reported to his superior (engineer, architect, or owner, as the case may be). The inspector should be reasonable in his relations with the contractor, and should, as far as he is able, endeavor to see that the contractor and owner both get a "square deal." The inspector should not be too rigid and arbitrary in requiring the contractor to conform exactly to the plans and specifications, neither should the inspector permit any material deviation, however slight, from the requirements that would materially injure the work. A good inspector, who understands his work, soon wins the confidence and respect of a good contractor. A good inspector can often do much to aid the progress of the work, and at the same time to secure a good, satisfactory, workmanlike job.

If the contractor and his workmen know how, and try, to do good work, the inspector's job is an easy one. If the contractor and his men know how, but appear unwilling, to do good work, care, firmness, and continued vigilance are required of the inspector. When the contractor and his men do not appear to know how to do good work, the inspector must be firm and tactful, and endeavor to teach the workmen the correct methods for securing good results. If the inspector does not know his work, or if he is tactless, overbearing, and overcritical, he may cause considerable trouble and expense, both for the owner and a good contractor. A dishonest contractor will often take advantage of a lax and ignorant inspector.

The duties of an inspector on concrete work may be summarized as follows:

1. *Excavation.*—The inspector should observe if the earth has been excavated to the depths and dimensions called for. In case of backfill, he should see that the earth is properly placed and tamped.

2. *Materials.*—No materials should be used until they have been inspected and approved as to kind, quality, sizes, etc. When required, representative samples should be collected for testing.

3. *Forms.*—The inspector must require that the forms be made and erected according to the requirements of the specifications and plans. He should check the dimensions inside of the column and beam forms. He should see that the forms are clean and properly wetted or oiled before the concrete is poured. He should require that all debris be removed from the inside of the forms, and that all openings for removing debris be properly closed before pouring concrete.

4. *Reinforcing Steel.*—When the steel is placed in the forms, the inspector should check sizes, bends, and spacing of rods. He should see that chairs and other steel supports and spacers are properly and securely placed, and that all ties are correctly made. In columns, the vertical rods must be securely tied to the spirals.

5. *Mixing Concrete.*—The mixing machinery must be clean and in good working order. No concrete should be mixed unless the inspector is on the job. He must see that the materials are charged to the mixer in the correct proportions (especially cement); that the correct amount of mixing water is used to give the consistency (and strength) called for; and that the concrete is thoroughly mixed before being discharged from the mixer. The mixing and transporting machinery must be washed and cleaned at the end of the run or of the day's work.

6. *Placing Concrete.*—The concrete should be taken from the mixer and placed in the forms before initial set has occurred. On the way from the mixer to the forms, the inspector should observe if the mix appears to have the right consistency and uniformity, and if there is any segregation of the materials. The inspector should note if the mix is carefully placed in the forms, and spaded and tamped to give a good dense concrete, free from air pockets, and with a smooth surface next to the forms. The

inspector must be careful to see that new concrete is carefully bonded to old concrete, according to the directions given.

7. *Curing of Concrete.*—The inspector should observe if the curing conditions are such as to give satisfactory results, and that the specifications are carefully followed in this respect.

8. *Removal of Forms.*—The inspector must see that the forms are removed at the correct time and in the proper order. The workmen should be careful not to chip, spall, or otherwise injure the concrete surfaces.

9. *Surface Finish.*—The inspector must note if all fins and projections are removed, and that all porous places are cut out and holes filled with suitable mortar or concrete. When a certain surface finish is required, the inspector must see that this work is properly done.

10. *Cleaning Up.*—After the work is completed and the structure and premises cleaned up, the inspector should make a final inspection to see if the cleaning is properly done, and that the place is left in good shape.

11. *Reports.*—The inspector should make all reports (usually daily ones) required of him in regard to his work. The reports may deal with materials delivered and used, forms made and erected, steel bent and placed, concrete mixed and poured, forms removed, surface finished, etc., as may be required by his superior. In addition to the routine part of the report, the inspector should note and report the general progress of the work, and any unusual or important matters dealing with the job. A diary, carefully and conscientiously kept day by day in regard to the work, is a great help.

SUPERVISION OF CONCRETE WORK

The supervisor or foreman in charge of concrete work should try to obtain average quality and maximum quantity of work in the minimum amount of time.

Foremanship, in general, consists of the ability to organize the gang, and to efficiently direct and supervise the work by properly dividing the work among the workers, educating the workers when necessary, coordinating the work of the different individuals, developing an *esprit de corps* or gang spirit, exercising tact and forbearance, and doing all that he can to secure satisfactory work at minimum cost.

Quality of concrete work depends upon good materials, proper tools and plant, correct methods of work, and good workmen. Good workmen in concrete are those who have sufficient education, skill, aptitude, and experience to turn out satisfactory work in an efficient manner.

Quantity of concrete work may be secured by use of good tools and methods, by correct location and arrangement of the plant, by proper organization of the gang, by the selection of good, efficient workers, by the development of gang speed, and by the avoidance of delays and idleness of the plant or of the workmen.

To be efficient, the concrete plant for a small concrete job must be of the right size for the job. The mixer should be located as close to the forms as practicable. The pile of coarse aggregate should be closer to the mixer than the pile of fine aggregate. The cement for a day's run (or at least for a half day's run) should be piled close to the mixer so that the mixer tender or operator can also handle the cement. The plant should be so laid out that the total amount of labor per cubic yard of concrete will be a minimum.

The concrete gang must be organized so that each man will be busy all the time. The time lost, due to delays and idleness, must be reduced to a minimum. Plant delays may be reduced considerably if the mixer operator keeps the mixer in good working order. Minor repairs, adjustments, greasing, etc. should be made outside of regular working hours. Idleness may be reduced by providing just enough workers for each class of work. For example, if two men can shovel and measure aggregates for the mixer, it is useless to have three men for this part of the work.

Motion and time studies are advantageous in determining the most efficient ways of doing certain kinds of work. The studies tend to show what motions are needed for a certain type of work and what motions are wasteful and unnecessary. After the proper method of doing the work has been found, the worker must be taught and trained to follow these methods until he does the work easily and efficiently. There is also a certain "knack," or way of doing work, that some men acquire more quickly than others. For example, an experienced shoveler in mixing concrete does not try to fill his shovel by a short stroke or a jab at the

pile, but slides his shovel on the mixing platform and fills it gradually and uniformly over a stroke of about 2 ft.

A foreman or superintendent should try by every possible means to avoid accidents to the workmen or plant. Accidents either to workers or plant cause delays and increased costs. Workers must be cautioned in regard to the use of certain parts of the plant, such as scaffolds, runways, ladders, etc. Plant accidents may be reduced by careful inspection at fairly close intervals. Guards should be provided for gears, chains, shafts, flywheels, etc., whenever practical.

The following are some of the principles for securing minimum costs of concrete work:

1. The sum of all of the units of cost should be a minimum.
2. The plant and men should be worked to capacity.
3. Delays and idleness should be reduced.
4. Plant and work should be arranged and organized to make the labor a minimum.
5. Low-priced men should be used for low-priced work, and skilled labor used only when required.
6. Overhead and plant expenses should be reduced to a minimum.
7. A gang spirit (idea of best company, best gang, best boss, best men in that class of work) should be developed.
8. The most profitable part of the work should be done first.

When investigating costs of concrete work it is well to express each cost item as a percentage of the whole. Any items which are exceeding the percentage values assigned to them should be studied as to the cause and possible remedy. When trying to reduce costs, it is usually better to study the larger items first. The most efficient work may not always mean the fastest work but it does mean the work which was done for the least cost.

The jobs in the Field Work Section are each divided into two parts—descriptive matter and field jobs or problems. In most instances, the descriptive matter is not intended to be complete but is intended to be supplementary to the material previously given in the text. While no back references are given, it is assumed that the preceding material has been studied and will be restudied when necessary.

The field jobs or problems are frequently divided into two parts, (*a*) and (*b*). When so divided, the object of jobs (*a*) is to observe, record, and study the work done by others; and the object of jobs (*b*) is actually to do the work. Study, observation, and practical work are all necessary for a thorough understanding on concrete practice.

JOB 79. CONCRETE BASEMENT—STAKING OUT

The best and easiest way to stake out a basement is by the use of surveying instruments. When such instruments are not

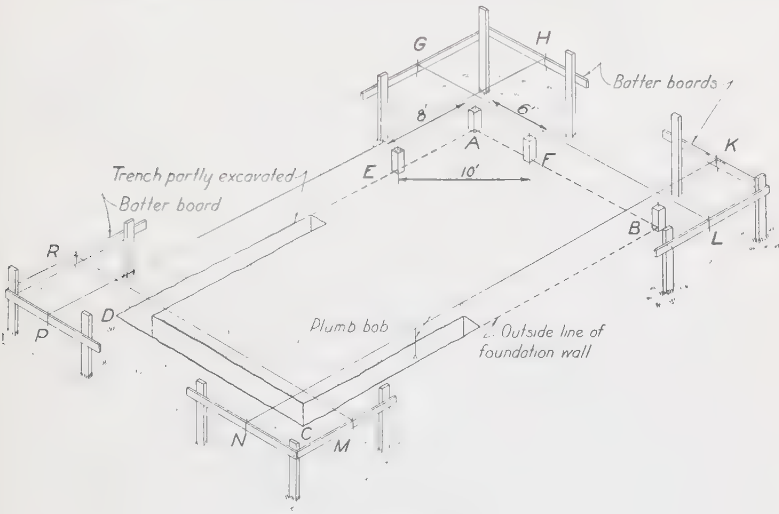


FIG. 81.—Method of staking out a foundation.

available, a 50- or 100-ft. steel tape may be used for measuring, and a carpenter's level and straightedge for leveling.

First a base line, marking one end or side of the basement, is established at the place where the proposed building is to be erected. Beginning at suitable points on this base line, lines for the other sides of the basement are laid out.

In Fig. 81, line *AB* is the base line, and stakes *A* and *B* are driven at the corners of the basement. Then the other lines *AD*, *BC*, and *CD* are located, and stakes sometimes placed at corners *C* and *D*. Nails may be driven in the tops of the stakes

to locate the exact corners, or the inside edges of the stakes may be used to determine corners, and the batter boards omitted.

Right angles may be laid out at any corner by the following method: Drive stake F (see Fig. 81) on line AB, and 6 ft. from stake A. Place nail in top of stake F exactly 6 ft. from nail in top of stake A. Drive stake E 8 ft. from stake A, and 10 ft. from stake F. Place nail in top of stake E exactly 8 ft. from nail in stake A, and exactly 10 ft. from stake F. Angle EAF is a right angle. Measure line AD (line AE prolonged), and locate point D. In like manner, lay off BC at right angles to AB, and locate point C. Measure BC for check.

For a final check, measure the diagonals AC and BD. These two diagonals should be exactly of the same length if the points A, B, C, and D form a perfect square or rectangle. If the lengths of the two diagonals are not exactly equal, move points C and D a little, and check distances again. Repeat process until the corners A, B, C, and D are located correctly.

Erect batter boards 2 or 3 ft. from each corner, as shown in Fig. 81. The horizontal boards are often set level with the top of the proposed foundation wall, or a certain definite distance above or below. Suppose that the horizontal boards are placed at corner A first, and made level by use of the carpenter's level. Then the batter boards at corners B and D may be placed, and the elevations of the horizontal boards found by sighting along boards G and H, or by sighting along a leveled straightedge fastened to one of these boards. The elevations of the horizontal batter boards at C must be checked by sights from both B and D, and errors corrected.

Strings may be stretched vertically over the corner stakes A, B, C, and D by use of a plumb bob. Notches or nails are placed in the batter boards where the strings are fastened to mark the correct places in case the strings should be broken or removed.

After having located the basement corners and lines, it is comparatively easy to locate any piers, posts, columns, or other supports for the building, either inside or outside of the building line as the case may be.

Problems.—Stake out a building foundation for a basement 24 × 32 ft. in size, setting corner stakes, batter boards and strings, assuming that the top of the foundation wall at point A is to be 2 ft. above the surface of

the ground. Be sure that diagonals AC and BD check. Correct length of each diagonal in this job is 40 ft. Materials needed will be six stakes, twelve posts, eight boards, about fifty nails, a ball of heavy twine, a plumb bob, a good carpenter's level, a 50 or 100 ft. metallic tape, a straightedge, a hammer, and an axe.

NOTE.—Other dimensions for the basement may be selected, if desired.

JOB 80. CONCRETE BASEMENT—ESTIMATING

The estimate for a concrete basement will be divided into five parts:

1. Staking out.
2. Excavation.
3. Forming.
4. Concreting.
5. Removal of forms.

The method of staking out a basement was explained in the preceding job, and a list of materials given for staking out a simple rectangular basement. If old lumber is used, the cost of materials will be small. The labor required for staking out a simple basement will usually vary from 1 to 4 hr. for two or three men, depending on conditions.

The volume of earth to be removed in excavations will be equal to the area of the basement times the average depth of the bottom of the basement below the ground surface. When the ground surface is a plane surface (either level or inclined), it is comparatively easy to find this average depth. If the ground surface is rolling or uneven, the basement area may be divided into several small areas (from 25 to 100 sq. ft., for example), and the average depth for each area approximately determined. Then the volumes due to each area times its depth are computed and summed up to obtain the total.

For a small basement where the dirt is to be used for grading around the place, the dirt may be removed by two men with a team and a scraper, and a shoveler or two. When the dirt is to be hauled away, it is usually shoveled directly into wagons or trucks. On comparatively large jobs, steam shovels and drag-line scrapers may be used. Plows or picks may be used for loosening the dirt.

The form lumber for basement walls may be either 1-in. ship-lap or 1-in. boards, about 6 to 10 in. wide, and planed on one side.

If the outer dirt walls of the basement are firm and smooth, they will serve as outer forms. For braces and struts and shores, 2 × 4's are commonly used. On many jobs, the form lumber for the basement is carefully salvaged and used for rough lumber in

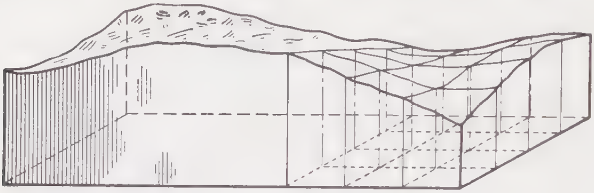


Fig. 82.—Method of computing excavation.

the building. Planks are usually provided for constructing runways for the concreting gang. For ordinary walls, the vertical struts or cleats may be spaced about 2 ft. on centers. A network of cross-bracing from one wall to the opposite wall is often used instead of the bracing of wall forms shown in Figs. 26, 27,

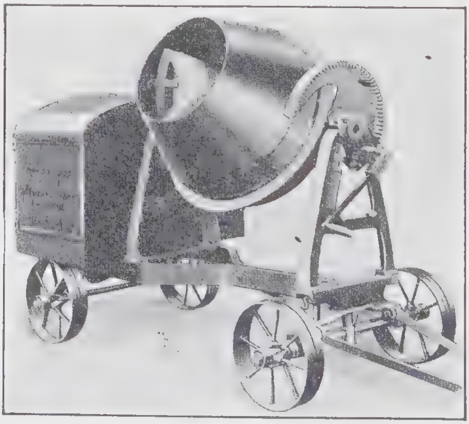


Fig. 83.—Small concrete batch mixer.

28, 84, and 85. When the braces extend from the vertical struts to the ground, the lower side of these braces must be securely butted against stakes driven in the ground, and the upper ends fastened to the vertical struts. Cross-bracing from wall to opposite wall is to be preferred.

For an average basement wall, the proportions of the concrete mix usually vary from 1:2½:5 to 1:4:7 when separate fine and coarse aggregates are used, and from 1:6 to 1:9 in the case of mixed aggregates (like bank run gravel). The thickness of the basement wall for a small basement may vary from 6 to 12 in., 8 in. and 10 in. being common.

In regard to concrete plant, a half-bag or a one-bag concrete mixer is commonly used. The crew required will vary from two or three men with a half-bag batch mixer to from four to six men with a one-bag batch mixer.

In building work, the basement wall forms are removed in about 10 days to 3 weeks after placing the concrete, and the form lumber carefully salvaged, nails removed, boards cleaned, and piled for later use. The labor cost of form removal may be quite large, but is worth while as the salvaged lumber is used again.

Problems.—Make a complete estimate of materials and labor for a basement with concrete walls. Size of basement is 24 × 32 ft., and walls are to be 8 in. thick and 7 ft. 6 in. high. Average depth to be excavated is 5 ft. 3 in. Concrete mix is to be 1 part of portland cement, measured by the sack, to 7 parts of bank run gravel, measured loose by volume as thrown into a measuring box or calibrated barrow or hopper.

NOTE.—If an actual basement is to be staked out and excavated, use dimensions for that basement.

1. Estimate materials and labor required for staking out.
2. Estimate quantity of excavation (in cubic yards) and labor (man, team, scraper, and two helpers).
3. Estimate form lumber in board feet, and labor in hours for forms. Assume outer dirt walls of basement to be firm and satisfactory as outer forms.
4. Prepare a bill of material for the form lumber.
5. Estimate quantities of cement and bank run gravel required.
6. Estimate labor and plant (mixer, barrows, shovels, etc.) for concreting, assuming a half-bag or a one-bag batch mixer for mixing, and barrows for placing the concrete.
7. Estimate labor required for removing forms, removing nails, and cleaning and piling form lumber.

JOB 81. CONCRETE BASEMENT—EXCAVATION

The excavation of small basements is frequently let for a lump sum or for a certain price per cubic yard. The lump sum contract is usually more satisfactory than day labor.

When the dirt is to be used for grading on the lot, no dump wagons or trucks are needed. The top soil is removed first by the scraper, and piled in one corner of the lot. This top soil is used for surfacing later on. A plow may be needed to loosen the soil from time to time. The scraper can remove about 80 or 90 per cent of all the dirt, and the remainder must be shoveled. Shovelers are required to square the corners, smooth the walls (if the dirt is comparatively stiff and firm), and to remove the last few cubic yards.

When the dirt is to be hauled away, dump wagons and teams are commonly used. A wagon is placed in the basement area and loaded by a shovel gang. The number of men in the shovel gang may vary from two or three to six or eight, depending on the desired time of loading the wagon. An extra wagon or two should be provided, so that a wagon can be loaded while the teams are on the road. The first team arriving unhitches from its empty wagon and hitches on to the loaded wagon. As the basement gets deeper, an extra team (snatch team) is required to help "snatch" or pull the loaded wagon out of the basement. The number of shovelers, wagons, and teams required depends upon the length of haul and desired rate of progress. The whole gang should be organized so that neither shovelers nor teams will be idle during the working hours. More than one wagon may be loaded at a time if the size of the basement permits.

Auto trucks are often not economical when they have to be loaded by shovelers. If the size of the excavation is large enough to warrant the use of a steam shovel, then auto trucks may be used.

When boulders are found, the smaller ones may be carried or hauled out of the excavation. Larger boulders may be broken by sledges, drills and wedges, or explosives.

Blasting is frequently necessary, when solid rock is encountered when excavating.

Problems.—*a*. Observe the work of excavating a basement for a residence, noting dimensions, quantities excavated, number of men, teams, wagons, scrapers, etc., on the job, and the work done by the different classes of labor, and the time spent on each class of work (plowing, scraping, shoveling, hauling, etc.). Compute the total hours of labor for both men and teams, and compare the results with reasonable estimates.

b. Excavate a basement, noting kind of earth, quantities excavated, number of men, teams, plows, scrapers, wagons, etc., used, and the corresponding time. Compare actual labor hours required with the estimated hours.

JOB 82. CONCRETE BASEMENT—FORMING

Under similar conditions, the amount of forming lumber required for a given basement will not vary greatly, but the

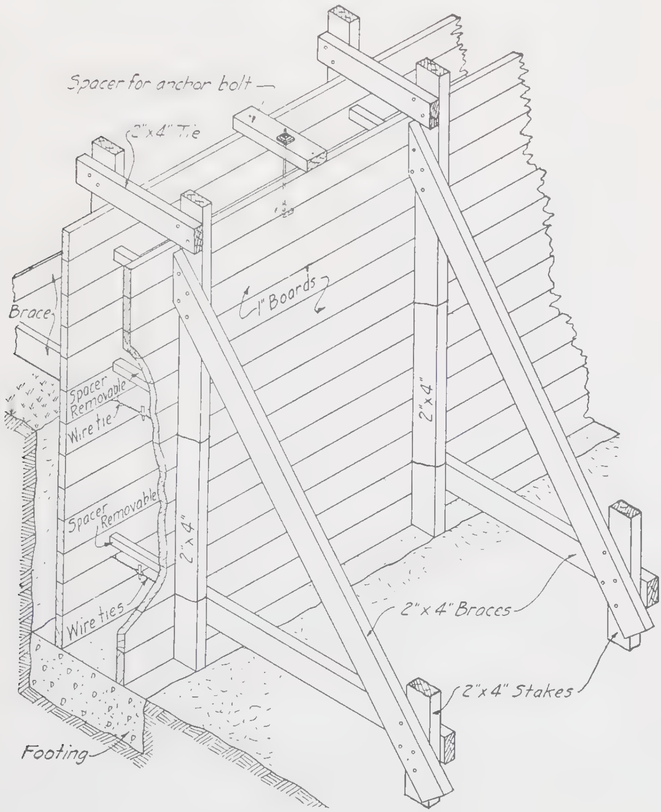


Fig. 84.—Foundation wall forms.

amount of labor hours expended may vary greatly. For example, experienced, capable, and fast men can build interior wall forms for a 20- × 30-ft. basement, with a depth of about 7 ft. in about 24 labor hr., while other workers may spend as much as 80

labor hrs. on a similar job. Building the forms for each wall on the floor of the basement, and then erecting them, often saves considerable time. No more nails should be used than necessary.

Pieces of lumber about 1 in. square, with a length equal to the thickness of the wall, make suitable spacers to keep the forms the required distance apart. These spacers may be removed as the concrete is placed.

Wire ties are satisfactory for keeping the forms from spreading.

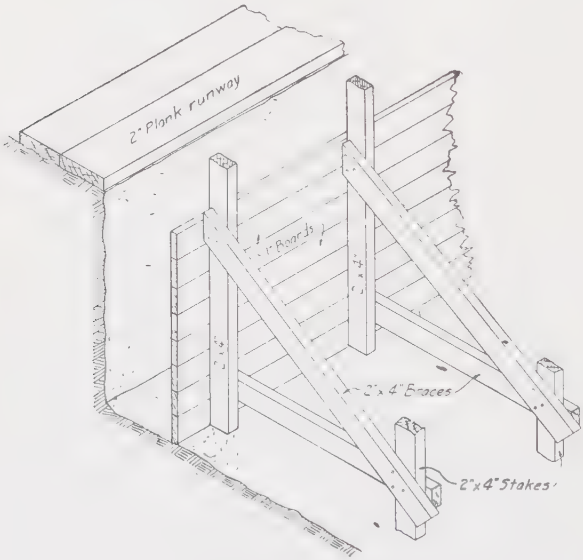


Fig. 85.—Foundation wall forms below grade. (The embankment serves as the outer form.)

If the form carpenters are to set the runway planks for the concrete gang, care must be taken to secure the planks so that they will not move easily when the barrows and men pass over them. Care should be taken in regard to projecting the ends of planks beyond supports. Such a plank may tip up and cause a serious injury to a workman.

Partially green lumber is usually satisfactory for form work, as dry lumber may swell, and too green or wet lumber may shrink.

Problems.—*a.* Inspect a job when basement wall forms are being constructed, noting the amounts, kinds, and sizes of the form lumber used, together with the nails, spacers, and ties. Make a bill of material for the forms. Record the hours of labor required to construct the forms.

b. If not previously done, make a bill of lumber and materials required for the wall forms for the basement previously excavated. Construct the wall forms for the basement, noting the materials used and labor hours expended.

JOB 83. CONCRETE BASEMENT—CONCRETING

Before starting the concreting work for the basement, the materials and plant needed should be on the job. The quantities are not large, comparatively, and there should be no difficulties in regard to the storage space needed.

The forms should be inspected to see if they are rigid and tight and well constructed. All rubbish should be removed from the interior of the forms. The surface of the forms with which the concrete will come in contact should be thoroughly wetted before concrete is poured. The surfaces could be oiled, but most builders prefer a good wetting with water.

The concrete plant should be examined to see if the mixer is clean and in good working order. Enough oil and gasoline should be on hand so that no delays will be caused by lack of them. The barrows, carts, shovels, and other tools to be used should be clean, and in good working order. The runways should be examined to see if they are well constructed and correctly placed for the work.

The crew for a one-bag mixer will be approximately as follows:

One man who acts as foreman, runs mixer, and adds cement and water to the mix.

Two or three men to measure and load the aggregates in the hopper of the mixer.

Two or three men to wheel and place concrete, depending on the capacity of the barrows or carts, and the size of the batch.

One man to spade (and sometimes tamp) concrete in forms so as to get smooth surfaces, to remove spreaders, place stop boards, etc., and help barrow men when necessary.

In general, the size of the crew should be such that the plant will be used efficiently and all men will be busy. A half-bag mixer will require a crew of about four men for efficient work.

Whenever possible, the pouring of the concrete basement walls should be finished in 1 day. If necessary to stop work for a day before the concreting is completed, the joints between the old and new concrete should preferably be made horizontal. On beginning work again, all laitance and dirt should be removed from the surface of the old concrete before the new concrete is deposited thereon. If several days should elapse before the concreting is resumed, laitance and dirt should be removed from the surface of the old concrete and this surface roughened. A rich, thin cement grout should be applied to the old surfaces before the new concrete is deposited. The new concrete should be placed before the grout has attained initial set.

When the forms are full, the tops of the walls should be leveled and smoothed off.

At the end of the job, at the close of a day's work, or at any time when the process of mixing and placing concrete is interrupted for 1/2 hr. or more, the mixer and barrows (and other tools with adhering concrete) should be cleaned and washed.

Problems.—*a.* Inspect a job when concrete basement walls are being poured, noting the size or capacity of mixer, size of batch, time required for mixing and placing a batch, the number of men in the crew and the duties of each, the amount of concrete mixed and placed, the time required, and the general methods of conducting the work.

b. Mix and place the concrete required to fill the forms constructed in Problem (*b*) of Job 82. Note organization and duties of workers, average size of batch, amount of concrete placed, required time of placing, and any other useful information pertaining to the work.

JOB 84. CONCRETE BASEMENT—REMOVAL OF FORMS

Basement wall forms should not be removed until the concrete has attained hard set, and has become strong enough to sustain its own weight and the loads that may soon be placed on it. The time required before the forms should be removed will vary from a few days in very hot weather to several weeks in very cold weather. Before removing the forms, the concrete should be examined to see if it is hard and firm.

The forms should be carefully removed, so that the lumber will not be broken or split, the concrete cracked, or the surfaces marred. Nails should be removed from the form lumber, the boards cleaned, and the lumber neatly piled for future use.

Fins and projections on the exposed concrete surface should be removed. Holes should be filled with a mortar of about the same proportions as that in the concrete. Spongy and porous places should be cut out, and the cavities filled with a concrete or mortar of the same proportions as that in the walls.

Problems.—*a.* Inspect a job when the forms are being removed from some basement walls, noting the appearance of the concrete, the care and manner in which the forms are removed, and the form lumber cleaned and handled, the amount of forms removed (square feet of form surface), and the labor hours required, the patching (if needed) of the concrete surfaces, and any other items of importance.

b. Remove forms from the basement walls of Problem (*b*) of Job 83. Remove nails, clean and pile lumber, and patch concrete surfaces. Note amount of form surface removed, labor hours required, and labor and materials required for patching surfaces.

JOB 85. CONCRETE SIDEWALKS—SPECIFICATIONS AND ESTIMATES

The following are general specifications in a condensed form for one-course and two-course concrete sidewalks. These specifications are practically the same as those proposed by the Portland Cement Association.

Cement.—Portland cement meeting the standard specifications for portland cement (Appendix 1).

Fine Aggregate.—Clean and well-graded natural sand or screenings, from a hard and tough crushed rock, gravel, or slag. All shall pass a No. 4 sieve, and 95 per cent or more shall be retained on a No. 100 sieve.

Coarse Aggregate.—Clean, hard, durable, uncoated pebbles, crushed stone, or blast furnace slag. All shall pass a 1-in. sieve and 95 per cent or more shall be retained on a No. 4 sieve.

Water.—Shall be clean enough to drink.

Joint Filler.—Premolded strips of bituminous filled fiber or mineral aggregate, $\frac{1}{2}$ in. thick, as wide as the thickness of the walk, and 2 ft. or more in length.

Forms.—Shall be of lumber 2 in. thick, or of steel of equal strength. Flexible strips may be used on curves. All forms shall be rigidly held to line and grade by stakes or braces.

Division Plates.—Shall be of $\frac{1}{8}$-in. steel, as wide as the depth of the walk, and as long as the width of the walk.

Subgrade.—Shall be well drained and compacted to a firm surface with uniform bearing power.

Drains.—When necessary, 4-in. concrete or clay tile drains should be laid to protect the walk from possible damage by frost action.

Subbase.—On poorly drained soil or where tile drains are impractical, a 5-in. subbase of cinders, gravel, or other porous material shall be used. This material shall be thoroughly tamped and drained to a street gutter or other outlet.

Thickness and Proportions of One-course Walk.—The concrete shall be at least 4 in. thick in residence districts and 5 in. thick in business districts. The proportions of the mix by volume shall be 1:2¼:4 for residence districts, and 1:2:3 for business districts.

Thickness and Proportions of Two-course Walk.—In residence districts, the base course shall be at least 4¼ in. thick of a 1:3:5 mix by volume. In business districts the base course shall be 5¼ in. thick, of a 1:3:5 mix by volume. The top course shall be at least ¾ in. thick, and the proportions of the mix shall be 1 part cement to 2 parts fine aggregate by volume.

Mixing.—Concrete shall be mixed until each particle of fine aggregate is coated with cement, and each particle of coarse aggregate is coated with mortar. A batch mixer is preferred.

Consistency.—The least amount of water should be used that will give a workable mix. The fresh concrete should require tamping to bring the water to the surface.

Placing and Finishing One-course Walk.—Concrete shall be placed immediately after mixing. It shall be tamped, struck off with a template, and then floated with a wood float until the surface has a true contour. Care shall be taken not to bring an excess of water and fine aggregate to the surface by overfinishing.

Placing and Finishing Two-course Walk.—The base course shall be thoroughly compacted by tamping, and then struck off with a template, which shall leave the upper surface of the base course ¾ in. below the finished surface. The top coat shall be placed within 45 min. after the base course is laid. The top course shall be struck off and finished with a wood float until the surface has a true contour.

Curing.—The new concrete shall be protected by a canvas or burlap covering for a day, after which the concrete shall be kept wet for 7 days.

Problems.—Prepare an estimate of the materials, labor, and plant required for 200 ft. of one-course, concrete sidewalk, 5 ft. wide, assuming the following:

Residence district.

Average depth of excavation is 8 in.

Subbase shall be 5 in. of cinders, with no tile drains.

NOTE.—Instructor may vary conditions of this problem to conform with requirements of the next two (*b*) problems.

JOB 86. CONCRETE SIDEWALKS—LOCATION, GRADE, BASE, AND FORMS

In residential sections, walks are usually placed along the property line and a strip of lawn or parking is left between the walk and the pavement. Walks in the interior of the lot may be

placed where desired, and, when carefully located, will add to, rather than detract from, the appearance of the property. It is usually better to curve walks around a fine tree, instead of removing the tree. The minimum width of walk in residence districts should be about 5 ft.

In business and industrial districts, the walks usually extend from the building line to the curb, in order to give the needed width. Stronger walks are needed in these districts.

In general, it should be planned to have the surface of the finished walk level with, or a trifle above (about 1 in.), the surface of the ground. Also the grade line of the walk should be approximately parallel to that of the pavement. A little study in regard to the grade line and location of the walk is well worth while when after effects are considered, especially when cuts or fills are encountered.

The slope of the walk for drainage should be about $\frac{1}{4}$ in. to the foot. The direction of the slope will often be determined by the slope of the surrounding ground. The slope may be to one side, to the other side, or to both sides, as desired.

In preparing the subgrade, the ground should be excavated to the depth desired, and all grass, sod, sticks, roots, and other vegetable matter removed. The surface of the subgrade should be tamped and compacted until it has a uniform bearing power. All soft and spongy places should be dug out and replaced with good earth, solidly tamped. Places in the subgrade that are harder than the average should be loosened and then tamped, so as to have the same bearing power (or degree of compactness) as the remainder of the subgrade.

Fills must be solidly compacted in about 6-in. layers. Muck, quicksand, sod, soft clay, spongy or perishable material should not be used. Fills should extend about 1 ft. beyond the edges of the walk to prevent undermining of the concrete during rains. When practical, it is well to allow the fill to settle for some time before the walk is constructed.

Good drainage of the subgrade is essential. If the subgrade is naturally well drained, no drain tile or cinders are needed. If the subgrade is water soaked, the best remedy is drain tile placed about 1 ft. or so under the walk, and near the edge from which most of the water comes. In many instances, a subbase of a

porous material (say a 5-in. layer of cinders) is advantageous. A drain must be provided to carry away the water from this porous material, or it cannot serve its purpose.

Sidewalk forms may be of wood or of metal. Straight forms should be of wood 2 in. thick, or of metal of equal strength. Flexible strips may be used for curves. Forms must be set true to line and grade, and securely held in place by stakes and braces. The top of the forms should correspond with the finished grade of the walk.

After the side forms are placed, division lines should be marked on them at intervals to locate the position of the cross forms and to mark the dividing lines to be cut through by the groover. The intervals should not exceed 6 ft., and 5-ft. intervals are common in most localities.

Metal cross forms have been found to be very satisfactory. These forms should be placed at the marked intervals, so as to be perpendicular to the walk surface and to separate the slabs.

Construction joints are the separation planes between the slabs, and are formed by the removal of the metal cross forms. The edges of these joints should be slightly rounded.

Expansion joints are placed at intervals of about 50 ft. in the walk, and between the walk and the curb, or a wall or a building. Expansion joints are usually 1/2 in. wide, except that a 1-in. joint should be provided between walks and curbs. The joint filler should preferably be a bituminous-filled fiber 1/2 in. thick as wide as the walk is thick, and as long as the walk is wide.

Problems.—*a*. Inspect the preparation of the subbase and forms for a concrete sidewalk, noting the average depth of excavation, condition of surface of subgrade, drainage (tiles, cinders, etc.), width, length, and thickness of walk, kind of walk (one or two course), kind of forms, workmanship in regard to placing of forms, provisions for cross forms and expansion joints, and labor expended for excavation, drainage, and forms.

b. Excavate and construct subbase and forms for a concrete sidewalk, as directed by the instructor. Note the amount of excavation, drainage provisions, amount and kind of forms, and labor required for excavation, drainage provisions, and forms.

JOB 87. CONCRETE SIDEWALKS—CONCRETING, FINISHING, AND CURING

Before starting concrete work, the forms and subbase should be inspected to see if they are correctly constructed, and the

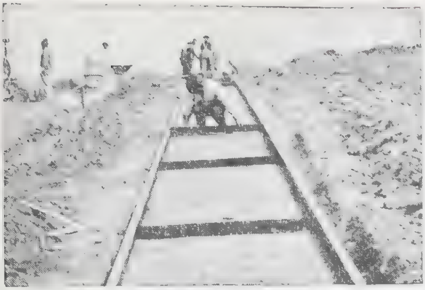


FIG. 86.—Side forms are set, the subgrade smoothed off and metal division plates installed.

FIG. 87.—Concrete is dumped onto the subgrade by barrows or direct from mixer bucket.

FIG. 88.—The concrete is spaded against the forms and then struck off with a screed or template.

FIG. 89.—This wooden screed is worked back and forth, bringing enough mortar to the top to make a smooth surface.

FIG. 90.—A wood float or belt smooths the surface and the edges are rounded with an edging tool along the side forms and the division plates.

FIG. 91.—After the surface is finished, the division plates are lifted out, the surface is protected with canvas and kept wet for a week.

FIGS. 86–91.—Construction of one-course concrete sidewalks.

concrete plant examined to see if it is clean and in working order. The materials for the work should be available on the job, or at least enough of the materials for a day's work. Shortly before starting concreting, the surfaces of the metal forms should be well oiled, while the wooden forms may be oiled or wetted.

If a half-bag batch mixer is used, the concreting gang will probably consist of from two to four men, mixing and placing concrete, and one finisher. With a one-bag mixer, from four to seven men may be used for mixing and placing, and one finisher and one helper for finishing. Two-coat work requires more labor for mixing and placing than one-coat work does.

Care should be taken, when measuring, to see that the materials are correctly measured. Placing materials in the mixer by shovelsful is not measuring. A bottomless measuring box should be used to measure the aggregates. Cement may be measured by the sack. Wheelbarrows may be used for measuring if their capacities are known, or if the inside of the barrow is marked to show the height to which the barrow is to be filled.

A batch mixer should be used whenever possible, and the mixing continued for at least a full minute. The drum must be completely emptied, before receiving the next batch. If hand mixing is used, precautions must be taken to secure thorough mixing (see Job 13, page 51).

In one-course work, the concrete is placed a little high in the forms, tamped, and then struck off by a template riding on the side forms. A heavy template will compress the concrete a little.

In two-course work the base course is placed at about the height of the side forms, tamped, and struck off by a template leaving the concrete surface $\frac{3}{4}$ in. below the top of the forms. The wearing course is placed soon after the base course (never more than 45 min. later), tamped, and struck off ready for the finisher. If the base course has commenced to harden before the top course is placed, the top course may crack and scale off.

Concrete for each slab should be placed continuously, so that all parts of each slab will harden together.

Whenever work must be stopped, as at the noon hour, or at the close of the day, it is best to stop work only at the end of a slab.

Fig. 92.—A base course of dry mix is tamped $\frac{3}{4}$ inch below the finished grade.

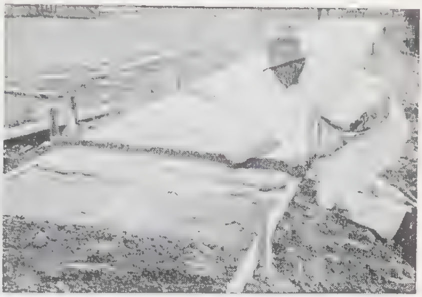


Fig. 93.—The $\frac{3}{4}$-inch mortar top follows close after the tamping and is struck off with a screed or template.

Fig. 94.—After the striking-off process the surface is finished with a wood float and the edges tooled to a rounded corner.

Fig. 95.—When desired, a very smooth finish may be obtained by using a steel trowel.

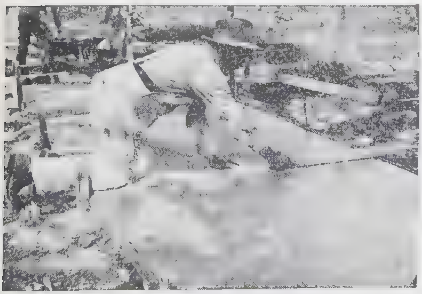


Fig. 96.—At regular intervals a dry sand joint is made in the base-course; the mortar top is grooved above this joint.

Fig. 97.—Edging tools are used, both along the forms and at the cross joints to give proper finish to the walk.

Figs. 92–97.—Construction of two-course concrete sidewalks.

Most concrete walk surfaces are now finished with a wood float, as a metal float makes a smooth slippery surface. After the concrete has been struck off, it should be smoothed with the float, high spots leveled off, low spots filled, and excess water worked to the edges of the side forms. Too much troweling brings water to the surface, and causes a chalky surface. Float marks may be removed by brushing the surface with a calcimine brush dipped in water. If a rough surface is desired, this may be made by lifting the wood float vertically away from the surface.

The edges of each slab next to the side forms and construction joints should be rounded to approximately a $1/4$-in. radius with steel edging tools.

Figures 86 to 97, inclusive, give a good idea of the methods of finishing one- and two-course concrete walks.

Special surfaces may be obtained by using different types of aggregates for the top surface, or by finishing the surface by different methods.

When colored effects are desired, only mineral coloring matter should be used, so as not to reduce the strength of the concrete. The weight of the coloring matter should not be more than 8 per cent of the weight of the cement. The cement and coloring matter should first be mixed dry. A sample should be made first, to see if the proportions selected give the desired color effect. The following mineral colorings may be used to secure various colors:

Color	Coloring Material
Pink to red	Red iron oxide
Browns	Brown iron oxide
Yellow to buff	Iron hydroxide
Gray to blue slate	Carbon black or manganese dioxide
White	White cement, white sand, and white rock

Concrete hardens best when kept moist. Consequently, immediately after the surface of the walk is finished, the walk should be covered with canvas or burlap placed a little above, and not in contact with, the surface. This covering may be removed after a day or so, and the walk kept wet by sprinkling for a period of at least 7 days.

After 1 week or 10 days, the side forms may be removed and earth tamped in the holes left by the forms.

Problems.—*a.* Inspect the concreting and finishing of a concrete sidewalk, noting the length, breadth, and thickness of the walk, whether one- or two-course work, proportions of mix, kind of plant, size of mixer, crew and their duties, the amount of concrete placed in cubic feet, and in square feet of walk surface, and the labor hours used.

b. Concrete and finish the concrete sidewalk for which the subgrade and forms were constructed in Problem (*b*) of the preceding job (Job 86). Note the organization of the crew, the amount of concrete placed, and the labor required. Pay careful attention to the curing of the concrete. Remove forms after an interval of 1 week or 10 days.

JOB 88. CONCRETE CURBS AND GUTTERS

There are three classes of concrete curbs and gutters: (1) separate curb; (2) combined curb and gutter; and (3) integral curb and gutter. Separate concrete curbs are rarely made, because of the joint next to the curb, where the water may work

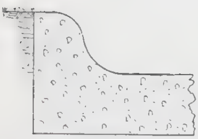


Fig. 98.—Cross section of integral curb and gutter.

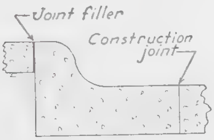


Fig. 99.—Cross section of combined curb and gutter.

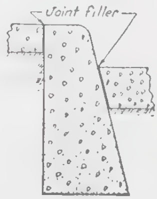


Fig. 100.—Cross section of separate curb.

through to the subbase. Combined curbs and gutters are good, though there is a joint between the gutter and the pavement. The integral curb and gutter are constructed simultaneously with the concrete pavement, and without any joints between the pavement and curb and gutter.

The face of a concrete curb should be sloping and the corners well rounded, because such a curb and gutter are more easily kept clean and also cause no damage to tires, rims, and wheels of motor cars, parked alongside the street.

The construction of the integral curb and the combined curb and gutter is illustrated in Figs. 101 to 112, inclusive. Typical cross-sections are shown in Figs. 98, 99, and 100. The height and width of the curb and gutter vary in different localities and on different jobs. Metal form surfaces should be oiled, and wooden form surfaces may be oiled or thoroughly wetted shortly before concreting.

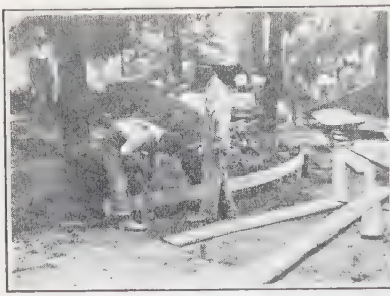


FIG. 101.—Setting curb forms on returns.

FIG. 102.—Building up integral curb on returns.

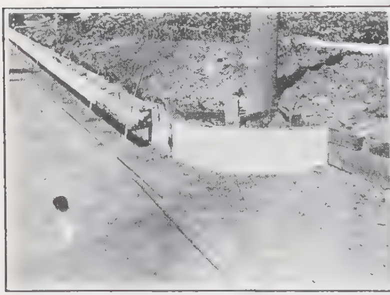


FIG. 103.—A simple form for integral curb.

FIG. 104.—Facing the curb after forms are removed.

FIG. 105.—Finishing with specially shaped trowel.

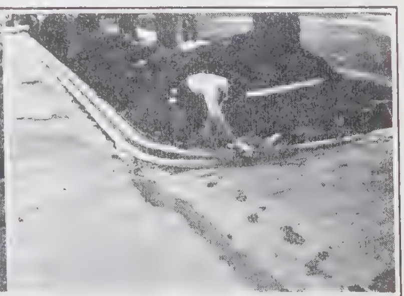


FIG. 106.—Giving final finish with brush.

FIGS. 101–106.—Construction of integral curb.

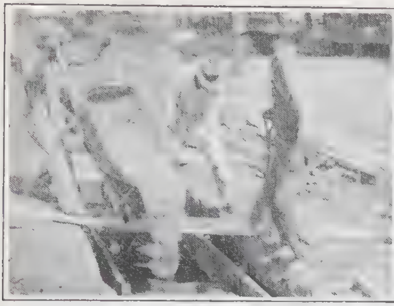


Fig. 107.—Placing concrete in forms.

Fig. 108.—Tamping concrete to approximate contour.

Fig. 109.—Striking off base course and mortar facing.

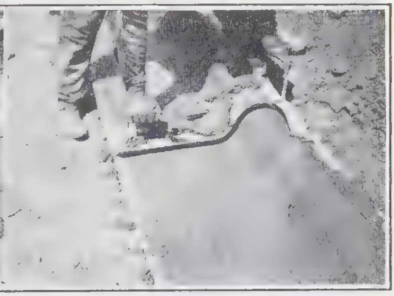


Fig. 110.—Finishing with curb machine.

Fig. 111.—Edging—note division plates.

Fig. 112.—Finishing with brush.

Figs. 107–112.—Construction of combined curb and gutter.

The following specifications are practically the same as those recommended by the Portland Cement Association:

Condensed Specifications for Integral Curb

Cement.—Portland cement meeting the standard specifications for portland cement (Appendix 1).

Fine Aggregate.—Clean and well-graded natural sand or screenings from hard, tough, crushed rock, gravel or slag. All shall pass a No. 4 sieve, and 95 per cent or more shall be retained on a No. 100 sieve.

Coarse Aggregate.—Clean, hard, durable, uncoated pebbles, crushed stone, or blast furnace slag. All shall pass a 1 ½-in. sieve and 95 per cent or more shall be retained in a No. 4 sieve.

Water.—Shall be clean enough to drink.

Joint Filler.—Shall be premolded strips of bituminous filled fiber or mineral aggregate ½ inch thick, and of the actual section of the curb.

Forms.—Shall be of lumber 2 in. thick or of steel of equal strength. Flexible strips may be used on curves. Shall be held in place with suitable clamps to prevent bulging.

Subgrade.—Shall be well drained and compacted to a firm surface, with a uniform bearing power.

Proportions.—Shall be 1 part cement, 2 parts of fine aggregate, and not more than 3 parts of coarse aggregate by volume, or the same as are used for concrete pavement.

Expansion Joints.—A ½-in. expansion joint shall be made at every joint in the pavement, and should be in perfect alignment with the joint material. When curbs are molded to shape by use of forms, the joint in the curb shall be made with a tapered separator of oiled wood ½-in. thick at the top and cut to the exact section of the curb. The filler must effect a complete separation between adjacent sections of the curb.

Mixing.—Concrete shall be mixed until each particle of fine aggregate is coated with cement and each particle of coarse aggregate is coated with mortar. A batch mixer is preferred.

Consistency.—The least amount of water should be used that will give a workable mix. The fresh concrete should require tamping to bring the water to the surface.

Placing.—Concrete shall be placed immediately after mixing. It shall be tamped and spaded until a coat of mortar is adjacent to the forms, so that no coarse aggregate will show when the forms are removed.

Finishing.—Concrete shall be struck off flush with the top of the forms, and shall be given a true finish with a wood float and a brush. If stone pockets appear when forms are removed, they shall be filled with cement mortar and troweled. Corners and edges shall be rounded.

Concrete shall be struck off and finished true to cross-section. Finish with a float or curb tool and brush. Round the corners and edges. Forms to remain in place at least 24 hr.

Curing.—Finished concrete shall be kept wet for 7 days.

Problems.—*a.* Observe the construction of a concrete curb and gutter, and note details in regard to plant, materials, mix, forms, labor (organization and amount), and placing, finishing, and curing of concrete.

b. Make a complete estimate of materials, forms, plant, and labor required for 100 ft. of combined curb and gutter, using cross-sectional dimensions selected by the instructor. Set forms, organize gang, and construct the 100 ft. of combined curb and gutter. Record materials, labor, forms, and plant used. Compare actual quantities and results with those estimated.

JOB 89. CONCRETE PAVEMENTS—DESIGN, SPECIFICATIONS, AND ESTIMATES

A properly designed concrete pavement will be well located, well drained; will have a good firm foundation or subgrade of uniform supporting power; will be of ample width for the present and near future traffic; will have a section of the correct sectional dimensions for the kind of traffic and type of subgrade; will have well-constructed construction and expansion joints; and will be constructed of concrete of the most economical proportions and consistency.

The location of a city pavement is almost invariably determined in advance, and the location of a county highway nearly always. Relocation of highways and questions of grade, alignment, curves, cut and fill, drainage, subgrade, design of sections, etc., should be left to the judgment of well-qualified engineers.

Good drainage is very important, and often determines the "life" of the pavement. Well-constructed side ditches should be built to care for the surface drainage of highways and take the water away from the roadway, and thus keep the water out of the foundation. The bottom of the side ditches should preferably be at least $2\frac{1}{2}$ ft. below the center of the roadway, and the ditches should be of ample capacity. These ditches should be provided with outlets spaced not too far apart. Culverts should be used to carry the water from one side to the other under the roadway.

Subdrainage is not needed in some instances, such as in fills and where the foundation soil is naturally porous and well drained. Drain tile are required where the subsoil is not well drained or is not porous (such as clay). The drain tile should not be less than 4 in. in diameter, and should be provided with sufficient outlets to carry the water away from the foundation. Tile lines may be placed under the center of the roadway, under one edge, or under

each of the edges, and at a proper depth and slope efficiently to drain the water away from the foundation. The slope of a tile drain should not be less than 6 in. in 100 ft.

Most every highway has some cut and fill. Excavation usually does not cause much trouble if careful attention is paid to line, grade, width, and drainage. Drainage, both surface and subsurface, in cuts is important. Fills should be carefully built up in horizontal layers of not over 1 ft. in thickness. Each layer should be well compacted before the next layer is applied. When time permits, an embankment should be allowed to settle before any paving surface is applied on top of it. Large rocks, sod, sticks, stumps, etc. must be kept out of the subgrade.

The subgrade should be roughly made to approximately its final shape, and then trimmed, scarified, sprinkled (if not already

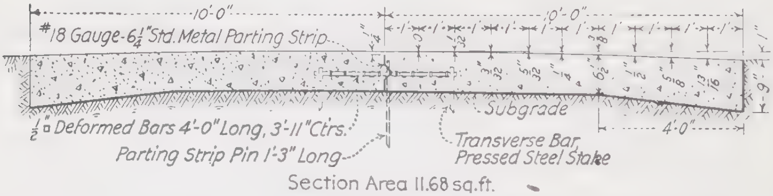


Fig. 113.—Cross section of standard concrete pavement—Wisconsin Highway Commission.

damp), and rolled until the surface is well and uniformly compacted and ceases to creep. Rollers, varying from 2 to 10 tons in weight, have been specified by different engineers for subgrade rolling. Soft spots should be dug out and replaced by good soil placed in 6-in. layers, and each layer well tamped and compacted. The contractor should be given extra compensation if required to excavate soft spots deeper than 2 ft. It may be advisable to place a 2-in. sand cushion on some soils such as clays. A uniform degree of compactness and supporting power is desired of the subgrade.

The roadway should be at least wide enough, so that two cars can easily pass when traveling at ordinary speeds. Widths of 16, 18, or 20 ft. are common, and greater widths are provided in instances where the volume of traffic demands it. Shoulders should be usually provided along each side of the highway pave-

ment. The width of the shoulders will vary in different localities and places.

The cross-section of a city concrete pavement may be of the same thickness throughout, or the edges may be a little thinner or thicker than the center, depending on the opinion of the engineer. The thickness should not be less than 5 in. at any place, and greater depths may be needed for certain kinds of soils and types of traffic.

The cross-section of a concrete highway should be made thicker at the edges than at the center, due to the tendency of

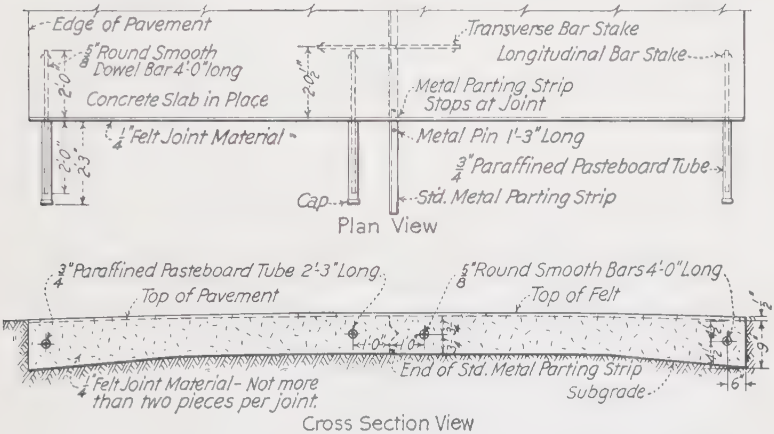


Fig. 114.—Transverse joint detail for standard concrete pavement—Wisconsin Highway Commission.

heavy trucks to stay near the edge of the pavement. The thickness selected depends on the foundation, traffic, strength of concrete mix, and amount of reinforcement. At the present time, the minimum thicknesses commonly specified are 9 in. for the edges and 5 or $5\frac{1}{2}$ in. for the centers, with 2 ft. or more for the taper. The Wisconsin Highway Commission uses 9 in. at the edges and $6\frac{1}{2}$ in. at the center, with a taper extending 4 ft. back from the edge. The Illinois Highway Commission uses a 9-in. edge with a center thickness of 6 in. for rural concrete highways, and a thickened edge and a 7-in. center for highways near large cities and population centers. Greater thicknesses may be required for very heavy traffic and weak and variable subgrades.

There is no doubt but that steel reinforcement is beneficial in concrete pavements, but engineers differ in their opinions in regard to the economy of the use of the reinforcement. The question is not yet entirely settled whether it is advisable to use steel reinforcement and a thinner slab or to use a thicker slab and no reinforcement. Ordinary pavement reinforcement may be steel fabric or steel rods properly formed into mats with dimensions of steel, spacings, and weights as specified. The amount of reinforcement may vary from 20 to 150 lb. per sq. yd. of pavement surface. Longitudinal parting strips are used in most concrete pavements 18 ft. or more in width, and dowel pins are provided

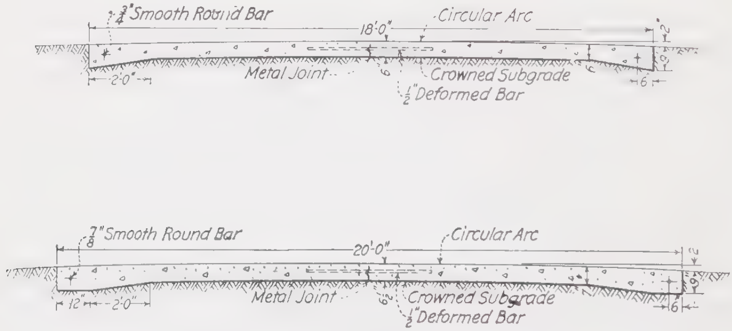


FIG. 115.—Illinois concrete highway sections.

in all transverse construction and expansion joints, so as to reduce and confine the cracking and to keep the edge of one section from rising above the edge of an adjacent section. Steel reinforcement is usually provided in concrete pavements where they pass over culverts or form approaches to bridges.

Transverse expansion joints should be spaced from 30 to 50 ft. apart, and should be about 1 in. wide. A bituminous-filled joint filler should be used, and not more than two pieces should be used in any one joint. Longitudinal expansion joints should be provided between the pavement and concrete curbs (unless integral curb and gutter is used), and other structures. When the pavement is over 25 ft. in width, a longitudinal joint is usually provided in the center. Longitudinal parting strips are now commonly placed in the center of concrete highways. Dowels should be placed as shown in the plans. Dowels in the

parting strip and longitudinal parts are $\frac{1}{2}$-in. square or $\frac{3}{4}$-in. round rods, 4 ft. long, placed 3 or 4 ft. on centers. At transverse construction and expansion joints, the dowels are usually $\frac{3}{4}$-in. round rods spaced about 4 ft. on centers. At transverse expansion joints, one end of each dowel is placed in a tube of paraffined or oiled paper to prevent this end from bonding with the concrete, and to permit expansion and contraction of the slab. Concrete pavement slabs often vary from 25 to 50 ft. in length and from 16 to 25 ft. in width.

When concrete pavements form approaches to bridges, the pavement section is usually widened, thickened, and reinforced.

On curves, the outer edge of the pavement is superelevated, and the width is widened (usually on the inside) to make travel safer. The amount of superelevation and widening varies in different localities. The free sight distance on a curve should be at least 150 ft., and many engineers prefer a minimum of 300 ft. when practicable.

Guard rails should be provided when the side slopes are so steep as to be dangerous, or when the highway passes over bridges and large culverts. These guard rails may be of several different styles. There are some patented forms of wire mesh on the market which make excellent guards, when properly placed and constructed. These wire mesh guards are designed so as to be elastic and to "give" to some extent when an auto hits them, thus tending to reduce the amount of damage to the vehicle and injury to the passengers.

The concrete materials should be inspected and tested to see if they comply with the specification requirements in each case before they are used in the concrete mixtures.

The proportions of the concrete mix vary in different localities. Wisconsin uses practically a 1:2:4 mix by volume, while other mixes are 1:2:3, 1:2:3½, etc. A 1:2:4 mix is about the leanest that should be used. It is often better to give a strength requirement and proportion the materials accordingly. The least amount of water should be used that will give a workable mix. The slump of a concrete highway mix should be about 1 in. as determined by the standard slump test. In no case, should the amount of water exceed 6¼ gal. per sack of cement with the aggregates dry. If aggregates are not dry, the amount of water

in them must be found and allowed for. This corresponds to a water-cement ratio of about 0.83 and should give a concrete having a unit 28-day compressive strength of from 2250 to 2750 lb. per sq. in. Some engineers specify the number of gallons of water per sack of cement that the contractor may use in the mix, and then let the contractor work out the grading of the aggregates to give the greatest yield and yet have a workable mix. In no case, should the amount of fine aggregate in a batch be less than half, or more than, the amount of coarse aggregate.

Any method of proportioning may be used that will give satisfactory results. Common methods are: measuring cement by the sack, and sand and coarse aggregate dry in measuring boxes; cement by the sack, sand inundated in a tank, and coarse aggregate dry in measuring boxes; and cement by the sack, and sand and coarse aggregate dry by weight. If aggregates are wet, the amount of water contained must be found and allowance made. The bulking effect of water in sand must be considered if the sand is wet. Water may be weighed or measured by any positive automatic device which may be set and locked.

The forms, plant layout, and mixing, placing, finishing, and curing of the concrete will be discussed in more detail in following jobs.

The specifications for Portland Cement Concrete Pavement for Highways given in Appendix 13 are good, and should be studied in detail in connection with the jobs on concrete pavements.

When preparing estimates for a concrete highway, the following items should be considered:

Cut and fill.

Culverts and bridge work.

Preparing subgrade.

Forms for pavement.

Concreting plant—including mixer, water pipes, tools, finishing apparatus, canvas and burlap pavement covers, trucks or narrow-gage railway for hauling materials from source of supply to the mixer, unloading plant at railway station, steam rollers, scrapers, etc.

Cement.

Fine and coarse aggregate.

Water.

Steel reinforcement.

Joint fillers.

Material for aiding the curing of concrete such as calcium chloride, hay and straw, sand, etc.

Shoulders for the pavement.

Guard rails.

Labor for all of the different construction items.

While the materials and plant needed may be estimated fairly accurately, it is more difficult to secure a reliable labor estimate, because of variations in labor skill and incentive to work, gang organization and spirit, possible delays due to weather and breakdowns, etc.

Likewise, it is difficult for the average person to estimate unit and total costs for similar reasons, though a contractor who knows his gang and their work can make a fairly close estimate.

Problems.—*a.* Make an estimate of the materials required for the concrete for 1.50 miles of concrete highway, 20 ft. wide, using the Wisconsin Highway Standard Sections and a 1 : 2 : 4 mix by volume, with expansion joints placed every 40 ft.

If practicable, make a complete estimate from the plans and specifications of a portion of a concrete highway in the process of being constructed, and check the estimate with actual quantities used on the job.

b. Prepare an estimate for a portion of a concrete highway pavement according to information given by the instructor in regard to the location, length, and section. Include estimates for preparation of subgrade, forms, concrete materials, plant, and all labor involved. This pavement section should preferably be a small section, such as may be later constructed by the class.

JOB 90. CONCRETE PAVEMENTS—SUBGRADE AND FORMS

The subgrade should be prepared as described in the preceding job and in Appendix 13. The length of subgrade that should be prepared ahead of the concreting crew will vary, depending on the length of the pavement that the concrete gang can lay in a day. Enough subgrade for from $\frac{1}{2}$ to 2 days concreting should be prepared in advance of the concrete gang.

The forms used may be either of wood or metal, but good metal forms are to be preferred. The specifications in Appendix

13 give the requirements for both wooden and metal forms and their setting.

FIG. 116.—Setting metal forms for concrete highways.

Problems.—*a*. Inspect the preparation of the subgrade and the setting of the forms on a concrete highway job, observing methods of compacting, wetting, and rolling subgrade, and kinds of forms, and methods of setting and aligning them. About what distance was the subgrade prepared and the forms set in advance of the concreting crew?

b. Prepare the subgrade and set the forms for the section of concrete pavement to be constructed later by the students. If the concrete is not to be placed soon, the subgrade must be inspected, checked, and wet down again, just before the concrete is placed. The estimates for this section of pavement were prepared by the students in a previous job.

JOB 91. CONCRETE PAVEMENTS—CONCRETE PLANT AND ORGANIZATION OF CREW

It is practically impossible to state just what should be included in a concrete plant for a concrete highway job, and to give the correct organization of the crew, because each concrete highway job is a separate problem by itself and requires a partic-

ular solution. Factors affecting this solution are equipment available, time limit of job, probable weather conditions, location of material supplies, location of job, kind and amount of labor available, and capacity and ability of contractor and his foremen.

In the following paragraphs, a description will be given of a plant layout, equipment used, and labor gang and organization. It should be noted that, while a certain plant layout and crew organization may give good results on a certain job, the same plant layout and crew organization might not work efficiently on other jobs, due to factors previously mentioned.

Most highway engineers prefer a mixer on the job to a central mixing plant, though the central mixing plant has proved to be economical in some instances. The mixer should be a batch

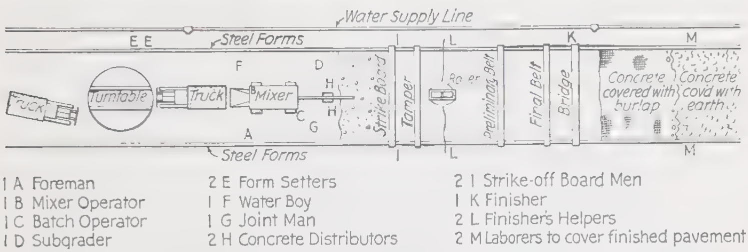


FIG. 117.—Concrete paving plant layout with three-bag mixer.

mixer with a boom and bucket delivery. The mixer engine may be steam, gasoline, or oil. Oil engines seem to be preferred at present. Electric motors may be used when there is a supply of electricity available on the job. The larger and medium-sized mixers should be able to move slowly under their own power. Smaller mixers can be moved a short distance by workmen when necessary. The sizes of mixers commonly used are 2-, 3-, 4-, 5-, and 6-bag batch mixers, with the larger sizes preferred, especially on large jobs.

The aggregates may be hauled to the job in advance of the work and placed on or along the side of the subgrade. This requires that the materials be handled again, usually by wheelbarrows. The cement, of course, cannot be placed on the job much in advance of the mixer. A water-tight platform (raised a few inches off the ground) and some tarpaulin covers will be needed for the cement.

The cement and aggregates may be hauled to the mixer in trucks or in industrial railway cars, and dumped into the mixer skip as needed. The aggregates should be correctly proportioned for each batch at the loading plant, and each truck or car may hold one, two, or three batches, depending on the capacities of the mixer and of the truck or car. The proper amount of cement for each batch should be placed in bags on top of the aggregate for that batch.

Motor truck haulage of materials is suitable for jobs and plants of all sizes, while industrial railways are often uneconomical, if used with smaller jobs.

When the aggregates are hauled directly from the sand and gravel pits and stone crushers, the aggregate supply companies will usually have all bins and loading devices necessary. When, however, the contractor hauls his aggregates from a railway siding, he will need machinery and appliances for unloading the cars and loading the trucks. When practical, the aggregates can be unloaded directly from the cars to trucks or bins. It is usually better to provide storage piles than pay demurrage charges. When the size of job warrants, bins should be provided for holding the aggregates and loading the trucks. Bins with weighing or measuring devices are needed when trucks are loaded by batches. A weather-tight cement storage shed capable of holding a carload or more of cement is often essential. With batch loading, this cement shed should be located near the aggregate bins, so that the required sacks of cement can be placed on top of the aggregates for each batch. A truck turntable at the job is a help when batches are hauled by trucks.

It is advisable to keep trucks, materials, etc., off of the prepared subgrade as much as possible. Any roughening or disturbance of the subgrade surface must be rectified before the concrete is placed.

A typical organization for a 3-bag batch mixer is as follows:

One foreman	One joint man
One mixer operator	Two concrete distributers
One batch operator	Two strike-off board men
One subgrader	One finish foreman
Two form setters	Two finishers or helpers
One water boy	Two laborers to cover finished pavement

Enough trucks and drivers should be used to keep the mixer well supplied with materials. The number of trucks needed will depend on the size of mixer or batch, the size of trucks, and the length of haul. One truck turntable man will be needed if a turntable is used.

If the cement and aggregates are piled on the job in advance, three or four cement handlers, five or six fine aggregate wheelers, and eight coarse aggregate wheelers are necessary. One or two trucks will be needed for hauling cement.

If the pavement is to be reinforced, one or two men will be needed to place reinforcement.

When the materials are unloaded at a railway siding, and batch haulage is used, one crane operator, one or two bin operators, one cement loader, two cement unloaders (from cars to shed), and possibly two shovelers will be needed. One foreman will be needed at the siding. When advisable, some laborers may be shifted from one kind of work to another.

Compared with a 3-bag batch mixer, a 6-bag batch mixer will require about 50 per cent more laborers and about twice as many trucks.

Problems.—*a.* Inspect a highway concreting plant in operation and write a report describing the plant layout and crew organization in detail.

b. In regard to the section of concrete pavement to be built by the class, overhaul plant available and place it in good working order, and determine the size of crew needed, crew organization, and duties of each laborer.

c. Prepare a detailed estimate of the organization required for a 6-bag batch concrete mixer, giving the number of laborers of each class and their duties. Assume batch haulage with trucks having a capacity of approximately 2 cu. yd. and an average length of haul of 3 miles from railway siding to job. How many trucks are needed? Plan the materials plant at the railway siding, and list the number of workers required and their duties.

JOB 92. CONCRETE PAVEMENTS—PROPORTIONING, MIXING, PLACING, AND FINISHING CONCRETE

Just before starting the concreting, the subgrade should be rechecked to see if it conforms to the specifications, and any irregularities corrected. The subgrade should be moist, so that it will not absorb water from the concrete. It is advisable to sprinkle the subgrade until it does not readily absorb any more water. When desired, the subgrade may be wet down from 12 to 36 hr., before placing the concrete.

The reinforcement of the type, size, and weight shown on the plans prepared by the engineer should be placed as directed in the specifications (Appendix 13). Care must be taken to secure the reinforcement in its proper place, so that it will not readily be displaced when the concrete is poured.

Any method of measuring the materials, including water, that will accurately give the required proportions is satisfactory. Aggregates should be dry, unless their water content is found

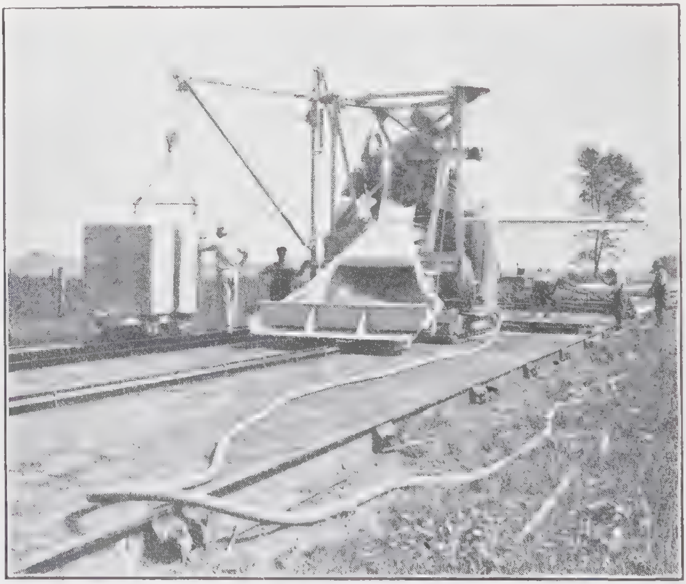


FIG. 118.—Charging the mixer.

and allowed for, or except when the sand is measured by the inundation method. The amount of water per sack of cement must be accurately controlled.

The mixer should conform to the specifications in regard to type and operation. Some engineers require a net mixing time of $1\frac{1}{2}$ min. instead of 1 min., as usually specified.

The mixed concrete should be deposited rapidly and uniformly over the subgrade. Tamping, spading, and slicing is advisable to remove air from the concrete, and to compact it thoroughly and uniformly.

A mechanical tamper is sometimes used as in the Vibrolithic process. In this process, a set of duck boards of definite size, with spaces between them, is placed on the fresh concrete, and a gas or oil engine, with an unbalanced flywheel, is pulled back and forth across the boards. The unbalanced flywheel, when rotating, acts as a tamper and thoroughly compacts the concrete. More coarse aggregate should be added from time to time, so that there will not be an excess of mortar on the pavement surface.

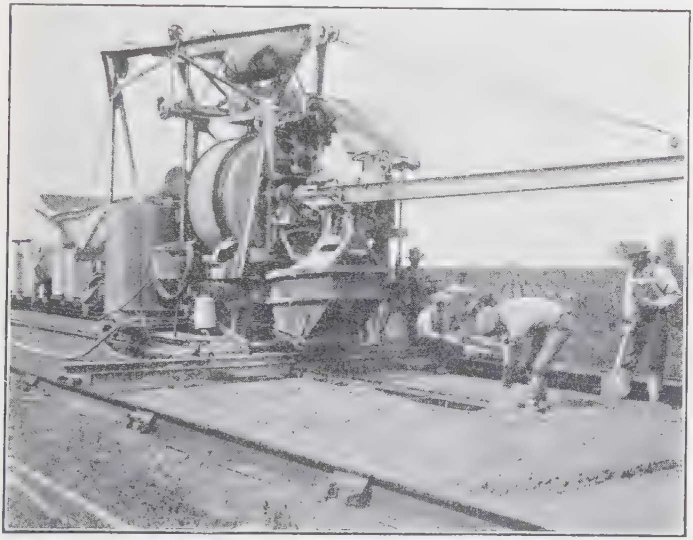


FIG. 119.—Spreading concrete on subgrade.

The concrete pavement surface may be finished according to any one of the methods given in the specifications. Some engineers prefer to roll the fresh concrete across the pavement with a 6-ft. wooden or metal roller after the concrete has been struck off, and before it has been belted. The roller should not weigh more than 50 lb., should have a smooth surface, and should be from 8 to 12 in. in diameter. The roller should be built in two sections, so that these sections may be separated a little when a joint is reached, and the concrete on both sides of the joint rolled in one operation. All portions of the concrete surface should have at least three separate rollings.

In regard to the finishing of joints and edges, some engineers prefer a $\frac{3}{8}$-in. or a $\frac{1}{2}$-in. radius instead of the $\frac{1}{4}$-in. radius, specified in the standard specifications.

Fig. 120.—Construction of a concrete highway.

Fig. 121.—Mechanical finishes.

The finished surface should be such that it will conform to the required form of cross-section without a deviation of more than $\frac{1}{4}$ in. at any place. In regard to the longitudinal trueness of

the surface, a 10-ft. straightedge placed parallel to the center line of the pavement should not show a deviation of more than $^1/_4$ in. The pavement surface should be tested for trueness before the last finishing operation is begun, and concrete removed or added as needed to give the required smoothness of surface. When concrete is added or removed at any point, the surface of this point must be completely refinished.

Problems.—*a*. Inspect the mixing, placing, and finishing of a section of a concrete pavement or highway, noting kinds and proportions of materials, plant details, pavement cross-section, reinforcement, joints, etc., and the methods of mixing, placing, and finishing the concrete. Note the amount of pavement placed in a day's run (square yards of surface and cubic yards of concrete), and compute the labor hours required per square yard of surface and per cubic yard of concrete.

b. Wet down the subgrade and mix, place, and finish the section of concrete pavement for which the subgrade and forms were prepared in the previous job. Compute labor hours required per square yard of pavement surface and per cubic yard of concrete.

JOB 93. CONCRETE PAVEMENTS—CURING

As the curing or hardening of concrete is not a "drying out" process, the concrete should be protected so that the moisture needed will not be evaporated. Concrete hardens best in the presence of moisture, hence the newly laid pavement should be covered or screened against the action of a hot sun or of a drying wind.

The standard specifications for concrete highway pavements given in Appendix 13 describe the protection of the fresh concrete by burlap or canvas covers, wet earth covers, and sprinkling or ponding. To be efficient, the covering must be kept wet.

Shrinkage cracks or "hair checks" are apt to form on the pavement surface during very hot and dry weather, due to the unequal shrinkage of the concrete and the exposed surface drying out a little. Working the pavement surface by tamping and belting until the hardening is fairly well advanced will help close shrinkage cracks, or help prevent such cracks from forming. Another method of preventing these shrinkage cracks is to cover the fresh concrete with burlap strips, and then keep the burlap moist, by spraying water through atomizing jets so as to keep a fine mist over it.

When the concrete has hardened sufficiently, so that shrinkage cracks will not form, but is not yet hard enough to permit pond-

Fig. 122.—Curing concrete pavement with burlap cover.

Fig. 123.—Curing concrete pavement with earth cover. Placing the earth cover.

ing or covering with earth, the pavement surface may be protected by canvas covers attached to frames. These frames span

the pavement and keep the canvas a short distance above the concrete surface. Every other frame should have a strip of

Fig. 124.—Curing concrete pavement with earth cover. Wetting earth cover.

Fig. 125.—Curing concrete pavement by ponding.

canvas to serve as a transverse partition across the pavement and thus prevent drafts along the surface. The canvas cover should be kept moist by spraying lightly with water.

When the concrete has hardened so that it may be covered with earth or ponded, the canvas-covered frames may be removed and the concrete surface protected for about 2 weeks by ponding or by an earth covering. Figures 122 to 126, inclusive, show various methods of protecting the newly laid concrete pavement.

When it is practically impossible to protect the pavement surface by coverings or ponding, as in the case of some city streets, the fresh concrete surface may be kept wet by sprinkler heads arranged at suitable intervals, and connected by a hose to the city's or contractor's water supply. The sprinkler heads

FIG. 126.—Curing concrete pavement with hay or straw cover.

should be adjusted so that the water will fall on the concrete in the form of a fine spray or mist.

Calcium chloride salt or crystals spread on the concrete surface (not less than $\frac{1}{2}$ lb. per sq. yd.) accelerates the hardening of the concrete, and tends to keep the surface from drying out too rapidly. The calcium chloride should not be applied until at least 24 hr. after the pavement is laid, and then only after the pavement has been kept thoroughly wet by sprinkling with water for the entire period, except the last hour just previous to the application of the calcium chloride. If rain falls within 2 hr. after the calcium chloride has been applied, an additional appli-

cation must be made. The calcium chloride should not be applied by shovels or brooms, but may be applied by a squeegee, or a suitable mechanical device giving a uniform distribution.

Coatings of sodium silicate and other materials have been used in some instances, but laboratory tests have not shown these coatings to be superior to ponding or moist earth covers.

In general, no such protective measures are necessary when the temperature is 50°F. or less. While concrete hardens less rapidly at low temperatures, there is but little evaporation of moisture from the concrete surfaces.

Concrete pavements preferably should not be placed during freezing weather (35°F. or less). Article 70 of the specifications in Appendix 13 gives instructions for cold weather work.

Before the highway is opened to traffic, shoulders should be constructed on both sides of the pavement. The material for shoulders should be of the kind specified, and should be placed, tamped, or rolled to conform with the requirements of the plans and specifications.

Problems.—*a.* Inspect the curing of a concrete pavement, noting methods used in detail for protecting the concrete surfaces, time required, and approximate labor needed.

b. Using the method selected by the instructor, protect the surface of the pavement placed in previous jobs for a curing period of 2 weeks.

JOB 94. CONCRETE SEPTIC TANKS

Briefly, the principle on which a small sewage disposal system operates is that of bacterial decomposition (or rotting) due to the action of bacteria. There are two classes of these bacteria: aerobic bacteria which require the presence of oxygen (air); and anaerobic bacteria, which do not need oxygen (or air). Usually the small sewage disposal system is composed of a septic tank, which is comparatively tight, and in which anaerobic bacteria work, and a distributing system, which may be a dry well, or a system of drain tile, and in which aerobic bacteria can work.

A concrete septic tank should be about 5 ft. deep, as experience has shown that a depth of about 4 ft. of liquid is essential, and of sufficient width and length to care for the average amount of sewage received in 1 day (about 50 gal. per person). Baffle plates should be placed close to the entrance and discharge pipes, or else

the tank should have a central partition so as to lower the velocity of the liquid through the tank. Concrete baffle boards about 2 in. thick are permanent. The length of the tank should be

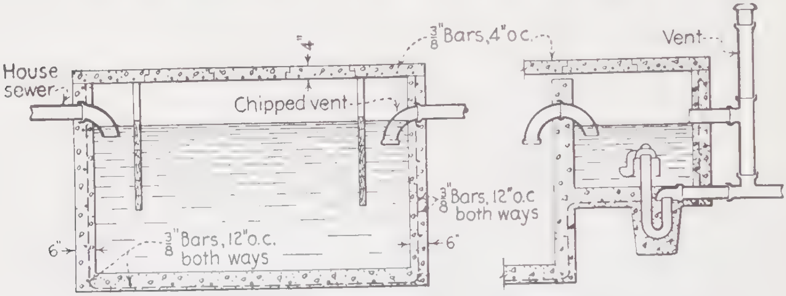


FIG. 127.—Cross sections of single chamber septic tank and siphon chamber.

approximately twice the breadth. The sewage may be discharged directly into the distributing system, or into a siphon chamber. The top of the septic tank should preferably be com-

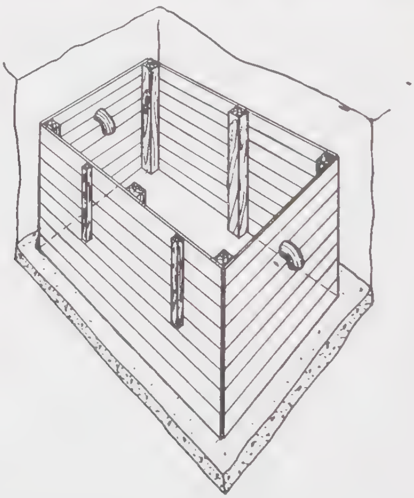


FIG. 128.—Forms for single chamber septic tank.

posed of tightly laid concrete plank, which may be removed when the tank requires cleaning. Many authorities prefer the use of a siphon chamber, especially when tile drains are used to distribute the sewage. The siphon causes a periodic discharge, which

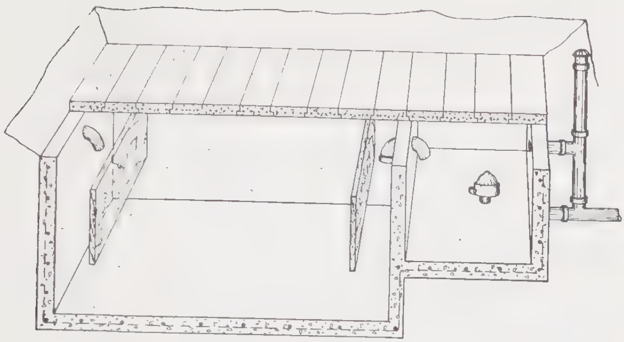


FIG. 129.—Septic tank with siphon chamber.

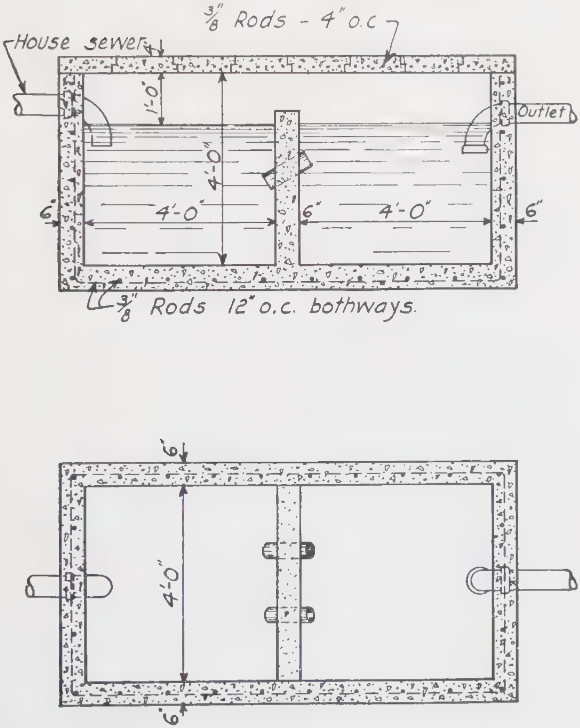


FIG. 130.—California type of septic tank.

tends to fill the drain tile for a time and to reduce the chance of clogging the tile near the septic tank. The use of a siphon is not so essential when a dry well is built.

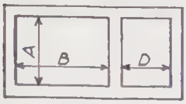
When drain tile are used to distribute the sewage, the tile may be arranged in two, four, or six lines and of sufficient length for the purpose. A longer system is required in a tight soil than in a porous one. The slope of the drain tile should be from 2 to 6 in. per 100 ft. of length. The table which follows gives approximate lengths of tile needed for tanks of various sizes and for different soils. Drain tile 4 in. in diameter is commonly used. The tile system should have an air vent, which is usually constructed near the septic tank and spihon chamber.

A dry well makes a satisfactory distributing system when the well can be carried down to sand or gravel, or to rock crevices. The bottom of the dry well should be 5 ft. or more below the bottom of the septic tank, and the horizontal cross-sectional area of the dry well should be about four or five times that of the septic tank. The dry well may be walled up with stone or brick laid loose, and a concrete cover provided. This cover preferably should not be lower than the top of the septic tank. The cover should be provided with a suitable manhole and cover for cleaning purposes, and an air vent should extend from the top of the dry well to the ground surface.

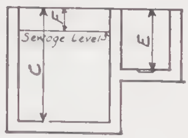
In most instances, the dirt walls of the excavation may be used for outer forms of the septic tank and inner forms of wood constructed as in Fig. 128. The walls and bottom of the septic tank should be 5 or 6 in. thick, and should be reinforced with woven wire or with 1/4-inch round rods spaced about 12 in. on centers in both directions. The reinforcement should extend down the walls and across the bottom of the tank, forming a kind of steel basket. The concrete mix should be about 1:2:3 by volume, good materials being used.

The cover of the septic tank should be made in the form of planks, as shown in Fig. 129. These concrete planks should be 4 in. or more thick, and reinforced in the bottom with 1/4-inch round bars running lengthwise of the plank. The thickness of the plank and the amount of reinforcement will depend partly on the depth of dirt over the top of the tank.

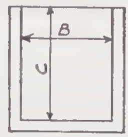
Figure 131, and the following table, give the dimensions of septic tanks of different capacities. These dimensions are the ones recommended by the Portland Cement Association. When a siphon chamber is not required, the tank may be constructed according to dimensions, *A*, *B*, *C*, and *F*. For tanks having a



Plan of tank with siphon.



Cross section of tank with siphon.



Cross section of single chamber tank.

Fig. 131.—Diagrams of septic tanks.

capacity of 750 gal. or less, 3-in. siphons are suitable, and 4-in. siphons are required for the larger tanks.

Dimensions of Septic Tanks

Maximum number of persons served	Capacity in gallons	Dimensions											Suggested length of tile system	
		A		*B*		*C*		*D*		*E*		*F*		
		Feet	Inches	Feet	Inches	Feet	Inches	Feet	Inches	Feet	Inches	Feet	Open soil, feet	Tight soil, feet
5	250	2	...	4	...	5	...	2	2	2	6	1	150	250
10	500	3	...	5	4	5	...	3	...	2	6	1	300	500
15	750	3	6	6	10	5	...	3	8	2	6	1	450	750
20	1000	4	...	8	...	5	...	3	10	2	8	1	600	1000
25	1250	4	6	9	...	5	...	4	3	2	8	1	750	1250

Problems.—Construct a septic tank of the size selected by the instructor. Compute materials required; excavate, build forms, and make and place the concrete. Concrete plank for the cover may be made above ground, and placed when the interior forms of the tanks are removed.

JOB 95. CONCRETE STEPS

Practically every home needs one or more flights of concrete steps, either leading from the basement or from the front and rear entrances, or connecting one walk with another. Concrete steps, when well constructed, are firm, durable, safe, and sanitary.

Forms for steps are usually of wood. For the side forms, 2-in.

plank should be used, and 1-in. material is usually satisfactory for braces and forms for risers. When desired, the forms for risers may be made to cause recessed panels in the risers. Forms for steps must be securely staked or otherwise fastened so as to be reasonably rigid. The form surfaces which come in contact with the concrete should be well oiled or thoroughly wetted a short time before the concrete is placed.

The earth forming the subbase should be thoroughly and uniformly tamped and compacted. Drainage must be provided, either by drain tile or a layer of porous material, such as cinders, if there is a reasonable chance of water collecting under the steps.

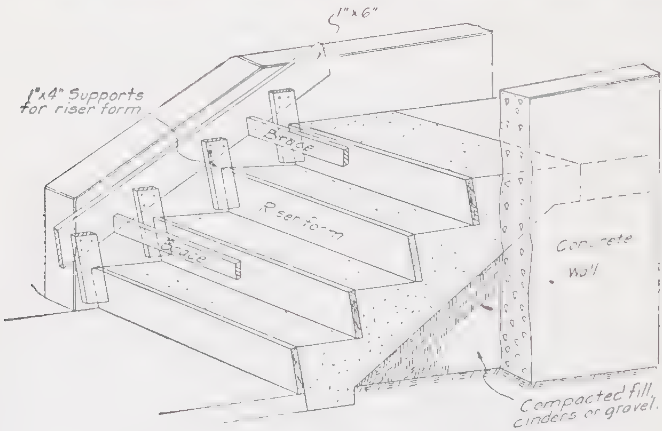


Fig. 132.—Forms and section of concrete steps.

In general, the concrete mix and consistency used for concrete steps should be the same as that used for the construction of concrete sidewalks. For separate flights of steps, a 1:2:3 mix by volume is recommended. The thickness of the steps at any point should not be less than 6 in. Figure 132 shows the method of construction of concrete basement steps. Side walls for steps in concrete walks may be provided or not, as desired.

The methods of mixing, placing, finishing, and curing of concrete for concrete sidewalks should be followed when making concrete steps. Wood floats should be used for finishing, as steel tools may make the surface too slippery. Steel tools are necessary for edging and rounding corners, etc.

Forms may be removed after a few days.

The steps should be covered for a day with wet canvas or burlap, and then kept wet for a week so that the concrete can "cure" and "harden" in the presence of moisture.

Problems.—Construct a flight of steps as directed by the instructor. Compute materials needed, excavate and compact subbase, construct forms, mix, place, and finish concrete, cure concrete, and remove forms.

JOB 96. CONCRETE WINDOW SILLS AND LINTELS

Precast concrete window sills and lintels have often been used instead of cut stone sills and lintels, and with satisfactory results in regard to labor required and appearance of the finished work. In general, precast sills and lintels are more economical than those cast in place in the walls.

There are two kinds of sills and lintels, those made in one section and those made in two sections. When the sill or lintel does not extend clear through the wall, and is not to have room plaster applied directly to one side of it, the one-piece lintel is satisfactory. A one-piece sill or lintel must be furred out for the lath and plaster, because otherwise water may pass through the concrete and show on the plaster.

The two-piece sill or lintel is one constructed in two sections, with an air space provided between the sections. This air space is necessary to prevent the passage of water through the concrete, or the condensation of water on the inside surfaces. The width of the air space may be $\frac{1}{4}$-in. or more, and the space must be continuous. Both sections of a lintel should preferably be of the same size or about the same size.

Lintels should be reinforced, so that they can properly carry the loads that will be applied to them. At least two reinforcing bars should be used for each lintel (one bar for each section, if the lintel is in two parts). In general, the cross-sectional area of the reinforcement should be from about $\frac{3}{4}$ of 1 per cent to 1 per cent of the cross-sectional area of the lintel. When placing lintels in walls, the reinforced side must be the lower one, that is, the reinforcement must be in the bottom of the lintel.

As the sills do not carry any appreciable load, they do not need to be reinforced, except, possibly, to reduce the chance of

breaking them in handling. A ¼-in. round bar placed about 1 in. from each corner of the sill will usually be sufficient.

The table which follows gives the reinforcement needed for lintels of various heights and used in different stories of the building. This table may be used for designing lintels for residences and ordinary store buildings, up to two stories and basement in height. For one-story houses, the first-story values may be used for the basement lintels, and the second-story values for the first-story lintels. For warehouses, larger and higher buildings than two story residences, and buildings subjected to heavy loadings, the design of the lintels should be left to the concrete-designing engineer.

NUMBER AND SIZE OF ROUND BARS REQUIRED FOR REINFORCING LINTELS OVER DOORS AND WINDOWS

Width of opening in inches	Basement				First story				Second story			
	Height of lintel in inches											
	6 to 9		9 to 12		6 to 8		9 to 12		6 to 8		9 to 12	
	Number and size of bars											
	Number	Size	Number	Size	Number	Size	Number	Size	Number	Size	Number	Size
0–28	3	½	2	½	2	½	2	⅜	2	⅜	2	⅜
28–36	2	⅝	2	½	2	½	2	⅜	2	⅜	2	⅜
36–48	2	¾	2	⅝	2	⅝	2	½	2	½	2	⅜
48–60	2	⅞	2	¾	2	¾	2	⅝	2	⅝	2	½
60–72	..	..	..	..	2	⅞	2	¾	2	⅝	2	½

NOTE.—Two bars are to be used for each lintel. Place one bar in each section of a two-piece lintel. Bars should be embedded ¾ in. from the lower side of the lintel as placed in the wall.

The forms for concrete sills or lintels may be made either of metal or wood. Metal forms are satisfactory when a large number of sills or lintels of the same size are to be made. Wooden forms are usually more satisfactory when a variety of sizes and only a few sills or lintels of each size are wanted. Glue, plaster, or sand molds may be used for making ornamental sills and lintels, as in making ornamental trim stone. Wooden molds may be kept from swelling and warping by giving them one or two

coats of shellac or linseed oil. Just before the concrete is placed, the form surfaces should be given a thin coating of form oil, to keep the concrete from sticking to the forms. Almost any clear oil that will give a thin oil film which will not stain the concrete will be satisfactory.

Forms should be designed so that they can be easily assembled and taken apart. The various form pieces should be of the exact size and shape required, and should fit together in such a manner that they may be easily pulled away from the concrete without injuring the surfaces or edges of the sill or lintel.

When desired, sills and lintels may be made with special surface finishes or facings, according to methods described in Sec. II.

The proportions of the mix for concrete for sills and lintels should be about 1:2:3 by volume. Fine aggregates should all pass the No. 4 sieve, and not over 5 per cent should pass the No. 100 sieve. Coarse aggregates should all pass the $\frac{3}{4}$-in. sieve, and not over 5 per cent should pass the No. 4 sieve. As little mixing water should be used as will give a workable mix. Concrete should be thoroughly tamped and worked in the forms to give the surfaces desired, free from voids and pockets.

The amount of hair cracks and crazing may be reduced by avoiding an excess of fine material (cement, stone dust, silt), by using as little mixing water as necessary, by placing and finishing the concrete so that a film of water and fine material will not be left on the surface, by not using steel finishing tools, if possible, and by keeping the concrete surfaces wet for about 1 week or 10 days after the concrete is placed.

Problems.—Estimate the materials required for forms and concrete, construct forms, and make some window sills and lintels according to the sizes and designs given by the instructor. Note labor required. Compute complete costs per cubic foot of concrete placed and per sill or lintel made.

JOB 97. PLAIN CONCRETE FLOORS

In this job, the construction of plain concrete floors laid on the ground is considered. Such floors are suitable for basement floors, barn floors, small garage floors, etc.

The following condensed specifications are for plain concrete floors, which are to be subjected to light and moderate traffic.

They may seem to be a little severe for basement floors for residences. These specifications are similar to the American Concrete Institute Tentative Standard Specifications for Concrete Floors.

Condensed Specifications for Plain Concrete Floors Laid on the Ground and Suitable for Moderate or Light Traffic

General Requirements

Portland Cement.—Shall meet the requirements of the Standard Specifications for Portland Cement as given in Appendix 1.

Fine Aggregate.—Shall consist of natural sand or screenings from hard, tough, crushed rock or gravel consisting of quartz grains or other hard material clean and free from any surface film or coating, graded from fine to coarse with coarse particles predominating. Dry fine aggregate shall all pass a No. 4 sieve, not more than 25 per cent shall pass a No. 50 sieve, and not more than 5 per cent shall pass a No. 100 sieve. Percentage of silt, clay, or loam shall not be more than 5 per cent. Tensile strength of 1:3 mortar briquettes should be equal to, or more than, that of standard Ottawa sand briquettes of the same mix and consistency.

Course Aggregate.—Shall consist of clean, hard, tough, uncoated crushed rock or gravel containing no soft, flat, and elongated particles, and being free from vegetable and organic matter. All coarse aggregate shall be well graded, and shall pass a $1\frac{1}{2}$-in. sieve, and not more than 5 per cent shall pass a No. 4 sieve.

No. 1 Aggregate for Wearing Courses.—Shall be of equal quality as coarse aggregate. All No. 1 aggregate when dry shall pass a $\frac{3}{8}$-in. sieve, and not more than 10 per cent shall pass a No. 4 sieve.

Water.—Shall be clean and fit to drink.

Reinforcement.—Should in general meet the requirements of the Standard Specifications for Steel Reinforcement of the A. S. T. M.

Joint Filler.—Should be a suitable compound which will not soften and run in hot weather or chip or crack in cold weather, or premolded strips of bituminous-filled fiber $\frac{1}{2}$-in. thick, and of a width equal to the thickness of the floor slab.

Measuring.—Shall be such as will insure uniform proportions and consistency at all times.

Mixing.—Concrete shall be mixed until each particle of fine aggregate is coated with cement paste, and each particle of coarse aggregate is coated with mortar. A batch mixer is preferred for mixing.

Retempering.—Retempering or remixing mortar or concrete that has partially hardened shall not be permitted.

Curing.—A freshly finished concrete floor shall be protected from the sun, wind, and rain until it can be sprinkled and covered. As soon as the finished floor has hardened sufficiently, it shall be covered with an inch of wet sand or 2 in. of wet sawdust, and kept wet by sprinkling with water for at least 10 days.

Subgrade. Shall be well drained and compacted to a firm surface with a uniform bearing power. All soft and spongy places shall be removed and filled with suitable material well tamped. A drainage system shall be provided when necessary.

Subbase.—When required, only clean coarse gravel or steam-boiler cinders free from ash and unburned coal shall be used. Thickness of subbase shall be at least 5 in. Subbase shall be thoroughly compacted and wetted before the concrete is deposited.

Forms.—Shall be free from warp, and of sufficient strength and rigidity. Shall be well staked or braced and held to established lines and grades, and their upper edges shall conform to the established grades of the floor. Forms shall be cleaned and thoroughly wetted or oiled before concrete is deposited.

Size and Thickness of Slabs.—The floor slabs shall be independently divided concrete block having an area not more than 100 sq. ft., or dimensions greater than 10 ft. If larger areas are required, the slabs must be specially reinforced. The thickness of the floor slab should not be less than 5 in. Thickness selected depends upon the loads, subbase, and strength of mix.

Joints.—When required, ½-in. joints shall be left between the slab and walls and columns of the building.

Edges.—Unless protected by metal, edges of slabs should be rounded to a radius of ½ in.

Consistency.—The least amount of mixing water that will give a workable mix shall be used for concrete and mortar mixes.

Reinforcement.—Slabs having an area of more than 100 sq. ft. or dimensions greater than 10 ft. shall be reinforced with wire fabric, or with plain and deformed bars. The reinforcement shall weigh not less than 28 lb. per 100 sq. ft. of floor surface. The reinforcement shall be placed upon, and slightly pressed into, the concrete base immediately after the base is placed. It shall not cross joints, and shall be lapped sufficiently to develop the full strength of the metal.

Two-course Plain Concrete Floors

Proportions for Base Course.—The concrete shall be mixed in the proportions by volume of one sack of portland cement, 2½ cu. ft. of fine aggregate, and 5 cu. ft. of coarse aggregate.

Placing Base Course.—After mixing, the concrete shall be handled rapidly and the successive batches deposited in a continuous operation, completing individual sections of the required depth and width. Under no circumstances shall concrete that has partly hardened be used. The forms shall be filled, and the concrete struck off and tamped to a surface, the thickness of the wearing course below the established elevation of the floor. The method of placing the various sections shall be such as to produce a straight, clean-cut joint between them, so as to make each section an independent unit. If dirt, sand or dust collects on the base it shall be removed before the wearing course is applied. Workmen shall not be

permitted to walk on the freshly laid concrete. Any concrete in excess of that needed to complete a section at the stopping of work shall not be used. In no case shall concrete be deposited upon a frozen subgrade or subbase.

Proportions for Mixture No. 1 for Wearing Course.—The wearing course shall be mixed in the proportions of one sack of portland cement and 2 cu. ft. of fine aggregate. The minimum thickness shall be ¾ in.

Proportions for Mixture No. 2 for Wearing Course.—The wearing course shall be mixed in the proportions of one sack of portland cement and one cubic foot of fine aggregate and one cubic foot of No. 1 aggregate. The minimum thickness shall be ¾ in.

Mortar Consistency for Wearing Course.—The mortar shall be of the driest consistency possible to work with a sawing motion of the strikeboard.

Placing Wearing Course.—The wearing course shall be placed immediately after mixing. It shall be deposited on the fresh concrete of the base before the latter has appreciably hardened, and brought to the established grade with a strikeboard. In no case shall more than forty-five minutes elapse between the time the concrete for the base is mixed and the wearing course is placed.

Finishing Wearing Course.—After the wearing course has been brought to the established grade by means of a strikeboard, it shall be worked with a wood float in a manner which will thoroughly compact it and provide a surface free from depressions or irregularities of any kind. When required, the surface shall be steel-troweled, but excessive working shall be avoided. A mixture of dry cement, sand and No. 1 aggregate may be applied to the fresh concrete of the base for a wearing course, but in no case shall dry cement or a mixture of dry cement and sand be sprinkled on the surface of the wearing course to absorb moisture or to hasten the hardening. Special methods not conflicting with these specifications may be used.

Coloring.—If artificial coloring is employed, only mineral coloring matter shall be used, and it must be incorporated with the entire wearing course, and shall be mixed dry with the cement and aggregate until the mixture is of a uniform color. In no case shall the amount of coloring exceed 5 per cent of the weight of the cement.

One-course Plain Concrete Floors

Proportions.—The concrete shall be mixed in the proportions of one sack of portland cement to not more than 2 cu. ft. of fine aggregate and not more than 3 cu. ft. of coarse aggregate, and in no case shall the volume of the fine aggregate be less than one-half the volume of the coarse aggregate.

A cubic yard of concrete in place shall contain not less than 6.8 cu. ft. of cement.

Placing.—(This is the same as for placing base course of two-course floors.)

Finishing.—After the concrete has been brought to the established grade by means of a strike board, and has hardened somewhat, but is still workable, it shall be floated with a wood float in a manner which will thoroughly compact it and provide an even surface. When required, the surface shall

be steel troweled, but excessive working shall be avoided. Unless protected by metal, the surface edges of all slabs shall be rounded $\frac{1}{2}$ in.

When desired, a terrazzo floor finish may be applied to any concrete floor.

A concrete floor surface may be made satisfactory for dancing by applying liquid soap and rubbing this soap into the pores of the concrete with a scrubbing brush. An application of powdered soap to a treated floor helps to keep it in condition. Another method is to apply paraffin wax, dissolved in turpentine, in sufficient quantity to fill the pores of the concrete. After the turpentine has evaporated and the floor surface is dry, powdered wax should be applied as in the case of a wooden floor.

There are various methods of treating concrete surfaces, which have been previously described in the text. When desired, most any of these methods may be used for treating concrete floor surfaces.

Problems.—*a.* Observe the construction of a concrete floor, noting preparation of subgrade and subbase, forms, dimensions and thickness of concrete slab, one- or two-course floor, proportions of mix, consistency, concrete plant, reinforcement, mixing, placing, finishing, curing, etc. Note organization of crew and labor hours required for each part of the work.

b. Construct a one-course concrete floor as directed by the instructor: (1) preparing a complete estimate of all materials, plant, and labor needed; (2) preparing the subgrade, subbase, and forms; (3) mixing, placing, and finishing the concrete; and (4) curing the concrete. Keep records of all materials and labor used.

JOB 98. CONCRETE CULVERTS—SPECIFICATIONS AND ESTIMATES

Concrete culverts are of three kinds: pipe, box, and arch. Pipe culverts are usually the most economical for small areas, while box and arch culverts are needed for larger areas. The selection of a culvert depends upon the size and character of the drainage area, available head room, depth of fill, kind of foundation, and the opinion of the person selecting the culvert. Sometimes box and arch culverts are built without a floor, and are called open-box or open-arch culverts. The present practice is to provide concrete floors for all concrete culverts unless the natural bed or floor should happen to be of comparatively hard

bedrock, so that the side walls will not be undermined by water.

A culvert, in order to be efficient, should have the same general direction as the flow of the stream; the bottom of the culvert should be lower at the discharge end than at the head end; the slope or inclination of the culvert bed should be about the same as that of the stream; the head walls or wings should be arranged to help the flow of the water; and there should be no projections in the culvert bed or obstructions near the entrance or discharge ends which would interfere with, and reduce, the free flow of the water. In general, the culverts should be placed across roadways and in the direction of the stream flow.

The size of the waterway or the culvert cross-sectional area required depends upon the maximum rate of rainfall, area and shape of the watershed, kind and condition of the soil, and the character and slope of the drainage surface and stream bed. The best way of determining the culvert area needed is to observe the flow of the stream during flood times, and to measure the cross-section of the stream at some narrow place near the culvert site.

When stream data is not available or reliable Talbot's formula may be used for finding the required culvert area. This formula is:

$$A = C\sqrt[4]{D^3}$$

where A = area of waterway in square feet
D = drainage area in acres
C = a coefficient, depending on the character of the drainage area

C varies from $2/3$ to 1 for steep and rocky ground; it equals about $1/3$ for rolling agricultural country subject to floods due to melting of snow, and with a valley length of three to four times its width; and equals about $1/5$, or less, in localities not affected by floods due to melting snow, or where the valley length is many times the width.

C should be increased for steep side slopes, especially when the upper part of the valley is much steeper than the channel near the culvert.

The following table gives the area of waterway required for various drainage areas:

WATERWAY OR CULVERT AREA REQUIRED

Drainage area in acres	Steep slopes	Rolling country	Flat country
	Culvert area in square feet		
10	5.6	1.9	1.1
20	9.4	3.1	1.9
30	12.8	4.3	2.6
40	16.0	5.3	3.2
50	19.0	6.3	3.8
60	21.5	7.3	4.3
80	27	9.0	5.4
100	32	10.5	6.3
125	37	12.5	7.5
150	43	14.5	8.6
200	53	18	10.5
300	72	24	15
400	89	30	18
600	121	40	24
800	150	50	30
1000	178	59	36

The length of the culvert will depend upon the width of the roadway and the depth of fill on top of the culvert. The slope of the earth fill can usually be taken as one and one-half horizontal to one vertical. In highway construction, the width of roadway should not be decreased at a culvert, as such practice is dangerous.

Head walls and wings should be built so that the embankment is protected and the flow of the water aided. These wings may be placed parallel with, or at right angles to, or inclined (usually 30 to 45 deg.) with, the axis of the culvert. Wings parallel to the roadway are often used for small culverts with low fills, and the wing walls are built up above the grade line to provide a guard rail. Flared wings are better on deeper fills, as these wings facilitate the flow of water and are economical in the amount of concrete required. Wings parallel to the axis of the culvert are sometimes used when the culvert is likely to be made longer in the near future. In general, the head walls and wings should be long enough to keep the culvert opening clear when earth falls around the ends.

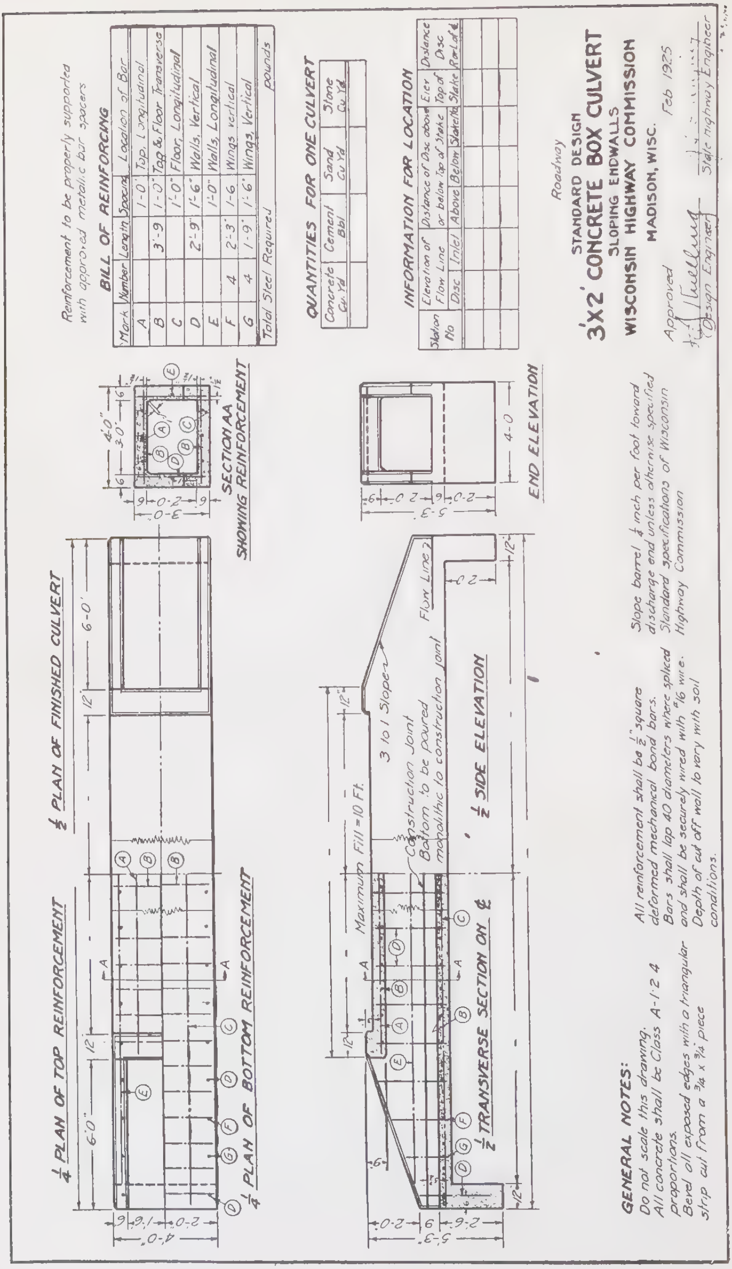


FIG. 133.—Concrete box culvert—Wisconsin Highway Commission.

Pipe culverts of cast iron, corrugated iron, vitrified clay, and plain and reinforced concrete are suitable in many places. Corrugated iron for small pipe culverts and reinforced concrete pipe for the larger sizes seem to be preferred at present. All pipe culverts should have concrete head walls to protect the embankments and the ends of the culverts. Reinforced concrete pipes up to about 6 ft. in diameter have been used.

Concrete box and arch culverts of many types have been designed and used. Most every State Highway Commission and Railroad Company has its own set of standards for these kinds of culverts. The design of a box or arch culvert depends upon the foundation conditions, depth and character of the soil, and loadings to be applied. Culverts of more than 6-ft. span are frequently classified as bridges.

Figure 133 shows a standard design of a concrete box culvert with sloping end walls prepared by the engineers of the Wisconsin Highway Commission.

Specifications for concrete materials and for concrete for plain and reinforced concrete culverts vary in different localities. The specifications of the Wisconsin Highway Commission for Concrete in forms given in Job 36, are typical. Clauses not applying to the particular job are omitted or crossed out. Class *A* concrete is preferred for the standard concrete box culverts.

Forms for culverts are often constructed of 2-in. plank, well supported, braced, and tied in place. Forms for the interior of a box culvert should be so made that they can be readily removed without damage to the concrete. Wedged braces may be used, with the wedges so made and placed that they can be readily removed.

The concrete should be allowed to cure or harden for at least 3 weeks in hot weather, or longer in cold weather, before the forms are removed. Exposed concrete surfaces should be protected from the rays of the sun and dry winds during the curing period. When practicable, the exposed surfaces should be covered with damp sand and kept wet for 1 week or 10 days after the concrete has attained initial set. If a surface covering is not practicable, then the concrete should be sprinkled twice a day.

Problems.—Prepare the materials estimate for the Wisconsin Highway Commission Concrete Box Culvert shown in Fig. 133, assuming an 18-ft.

roadway and a fill of 6 ft. over the top of the culvert. Estimate excavation, forms, reinforcement, cement, sand, and crushed rock, assuming Class A concrete. If an actual culvert is to be constructed, the roadway width, fill, culvert length, etc., in this job should be changed to conform with those for the culvert to be built.

Prepare an estimate of the labor required for this culvert, subdividing the estimate as follows: excavation, forms, bending and placing reinforcement, mixing and placing concrete, removal of forms, and backfilling.

JOB 99. CONCRETE BOX CULVERTS—EXCAVATION AND STAKING OUT

The best way is to stake out and construct the culvert before the fill is placed. When the fill is already in place, the dirt must be excavated to the bottom of the culvert floor. The bottom of the excavation should be true to grade and alignment. All soft and spongy places in the soil should be removed and replaced with good earth, well tamped to give a uniform bearing power. It is important that the dirt forming the subgrade be firm and compact to give a uniform bearing power. Trenches for the cut-off walls at each end of the culvert must be dug. The slope of the excavation should be such that there will be no trouble due to dirt sliding down on the subbase, or into the forms.

In staking out a culvert, stakes are driven to give the elevation, slope, or grade and alignment of the top of the culvert floor, as well as the general overall dimensions of the culvert. In general, the culvert will extend crosswise of the roadway, and its alignment and slope will conform to that of the waterway. Care should be taken not to have the culvert floor too far above or below the bed of the waterway, or too far out of alignment so as to obstruct the flow of water, or to reverse the slope of the culvert floor. This slope should preferably not be less than 1/4 in. to the foot. A convenient bench mark and reference stakes (offset a given distance to the side of the center line of the culvert) should be provided for the purpose of checking the elevation and slope of the culvert floor.

Problems.—*a.* Observe the staking out of a culvert, noting just what stakes are set, how they are set, and where.

b. Stake out a culvert. This culvert may be assumed to be placed under an existing roadway, or to be for a proposed new roadway. An engineer's level, level rod, and measuring tape should be used if available. Satisfactory work may be done with a good carpenter's level, straightedge, and measuring

tape, if engineering instruments are not to be had. Draw a sketch showing location of the roadway and all stakes set. If any excavating is needed, this should be done, noting quantity of dirt removed and labor hours required.

JOB 100. CONCRETE BOX CULVERTS—FORMS AND REINFORCEMENT

The forms used for large concrete culverts are usually of 2-in. plank well braced and tied. For smaller culverts, 1-in. boards

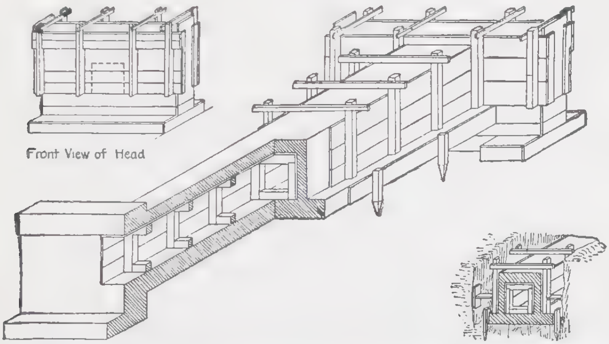


FIG. 134.—Forms for small box culvert, Mass. Hy. Commission.

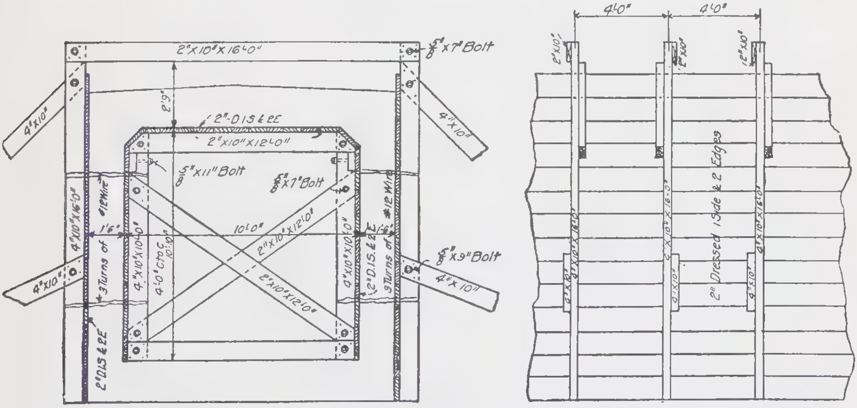


FIG. 135.—Forms for 10 × 10 ft. reinforced concrete box culvert, C. B. & Q. Ry.

may be used, if they are supported and held in place by cross-braces placed fairly close together. Figures 134 and 135 should be examined for details of culvert forms.

Care should be taken in the design of the forms so that they will be firm and unyielding, and yet be economical in regard to lumber and be easy to remove. Wedges, with the braces of the inside forms of a box culvert, aid in making these forms easy to remove.

The reinforcement bars should be carefully placed in position and wired together, so that they will not be displaced during concreting.

Problems.—*a.* Observe the construction of forms for a concrete box culvert, noting size and dimensions of the culvert, amount, kind, and dimensions of form lumber used for different parts of the forms, ties, braces, wedges, etc. Make sketches of the forms, if these sketches will help illustrate and explain the form construction. Note labor hours required, and number of square feet of form surface. Observe how the reinforcing rods are placed and secured in position.

b. Make a bill of material for the form lumber. Make sketches for the design of the form, if such sketches are needed. Construct the form for the culvert staked out in the preceding jobs, noting labor hours required. Place reinforcement bars in forms and secure them in position, noting labor hours required.

JOB 101. CONCRETE BOX CULVERTS—CONCRETING

Before starting concreting, the materials should be on the job, and the plant clean and in working order. Sometimes the mixer can be placed high enough above the culvert forms so that the concrete can be chuted into the forms. Usually runways and barrows or carts are used for transporting concrete.

The concrete is poured monolithic up to the construction joint, then the inside forms and the reinforcement bars for the top of the culvert are placed in position and the concreting finished. These inside forms should be previously prepared, so that they can be placed without appreciably interrupting the process of concreting. With good planning, the delay in concreting should not be over 20 or 30 min.

If more than 45 min. are required for the placing of the inside forms, the concrete surface at the construction joint should be roughened, cleaned of all loose concrete material, debris, and laitance, and a coat of cement grout applied before any new concrete is placed.

As the concrete is placed in the forms, it should be spaded so as to push the large aggregate away from the form surfaces and

to remove air pockets. A little tamping may be advisable thoroughly to compact the concrete in place.

All exposed edges should be rounded, and the exposed surfaces of the concrete should be finished when the concrete is placed.

Problems.—*a.* Observe the concreting of a concrete box culvert, noting the plant layout, organization of crew, method of placing concrete, amount of concrete placed, and time required.

b. Arrange the plant, organize crew, and mix and place concrete in the concrete box culvert forms constructed in the previous job. Note amount of concrete placed and labor hours required.

JOB 102. CONCRETE BOX CULVERTS—REMOVING FORMS

After the concrete has hardened, the forms should be removed in such a manner that the concrete will not be damaged. Concrete should be from 14 to 28 days old in warm weather, and older in cold weather, before the forms are removed.

After the forms are removed, the concrete surfaces should be gone over, fins and projections removed, and holes and spongy places dug out and patched.

The form lumber removed should be separated, nails removed, surfaces cleaned, and then piled for removal to another job.

The backfilling should now be done. The dirt should be placed in layers about 6 in. thick, and each layer tamped and compacted before the succeeding layer is placed. If a supply of water is available, thoroughly wetting the backfill will help settle the dirt.

Problems.—*a.* Observe the removal of forms, concrete surface cleaning and repairing, and backfill on a concrete box culvert job, noting amount of work done and labor hours required.

b. When the concrete of the box culvert made in previous jobs is 3 weeks old, remove the forms, and separate, clean, and pile the lumber; clean and patch concrete surfaces; and make all needed backfill, noting amount of work of each kind and labor hours required.

JOB 103. CONSTRUCTION OF REINFORCED CONCRETE BUILDINGS

The successful and economical construction of a reinforced concrete building requires very careful planning in regard to plant, forms, labor, rate of progress, and other construction details. As a building is larger and more complicated in detail than most of the structures described in previous jobs, the profit-

able construction of the building will, consequently, require much more care and thought.

The estimates for plant, materials, labor, and costs should be carefully made according to the principles given in Sec. IV.

The correct planning of the work is important. The preparation and use of progress charts, work schedules, and material schedules are almost a necessity on large jobs, and are an aid on smaller and medium-sized jobs.

The choice of plant, plant layout, materials storage, and similar items must be carefully thought out in advance. Sketches for the plant layout should be prepared on all large jobs.

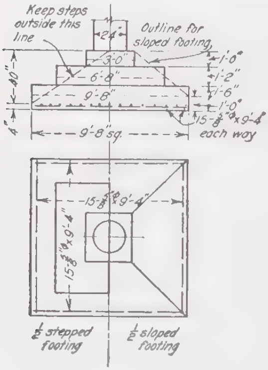


Fig. 136.—Isolated footing.

The excavation for the basement will usually be made according to the methods already given, except that trucks with a steam or gas shovel or drag line will probably be used on large jobs. In many instances, the walls of the excavation will need to be braced. A pump may be required for the removal of ground water. In special cases, it may be necessary to shore up or underpin the walls of adjacent buildings.

After the excavation is completed, the building foundations are constructed. These foundations may be in the form of separate or isolated footings for each of the columns and walls; combined footings (including the so-called cantilever footings), when one or more columns are carried by one footing; continuous footings, when the footing is continuous under a row of columns; and raft footings, which extend over the whole lot, support all columns, and are built monolithic. Raft footings are frequently used when the soil has but comparatively low supporting power. Piles are used under the footings when so required by soil conditions. Concrete footings (either plain or reinforced) appear to be the most economical at the present time.

The formwork, steel bending and placing, and pouring of concrete for the foundations rarely cause any trouble.

Location or key plans showing the location of columns and beams are almost necessary on all reinforced concrete building

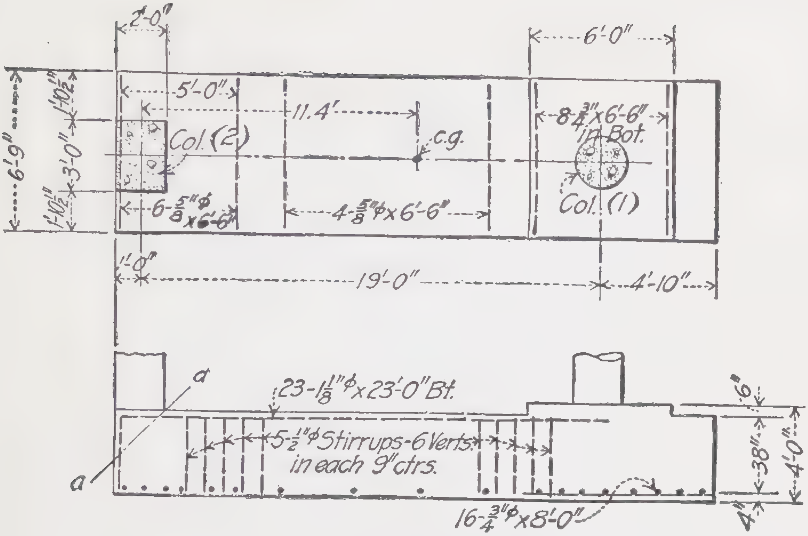


FIG. 137.—Combined footing.

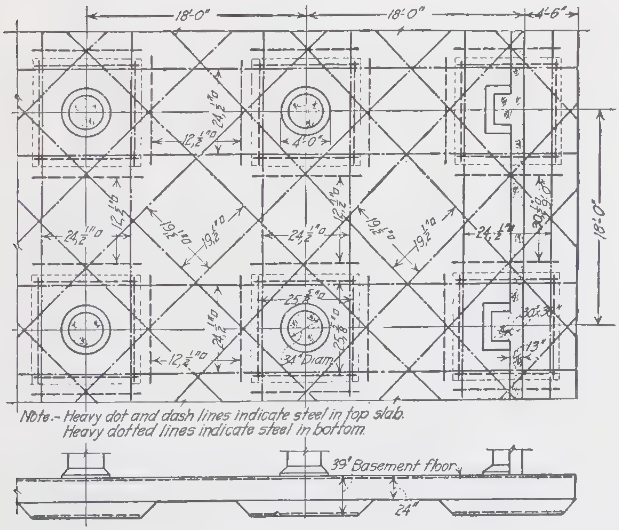


FIG. 138.—Raft foundation.

jobs. A general assembly plan of the formwork is a great help to the carpenters. Details of all general and special formwork should be drawn, and blueprints secured for the use of foreman and carpenters.

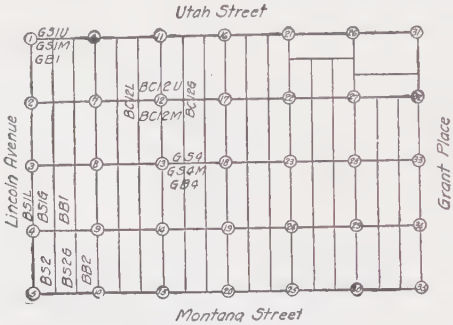


Fig. 139.—Location or key plan.

Most of the details of the construction of the forms for the columns and floors have already been covered in the preceding parts of the text. Metal column forms are frequently used.

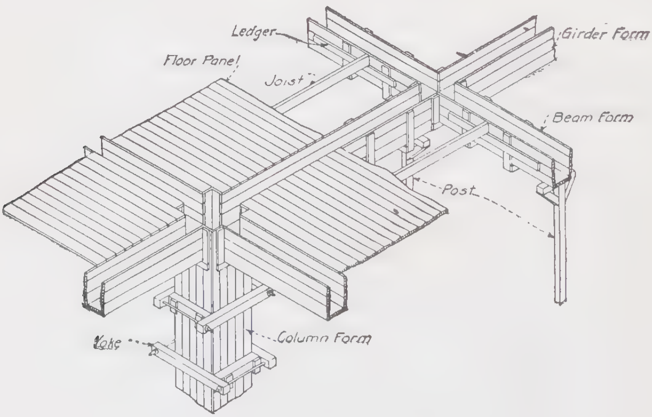


Fig. 140.—General assembly plan.

Both matched and edged lumber are commonly used for floor forms, though metal floor forms are gaining in favor.

The accurate bending, placing, and secure fastening or anchoring of the reinforcing steel in position are essential. Blueprints showing beam and reinforcing bar details are necessary.

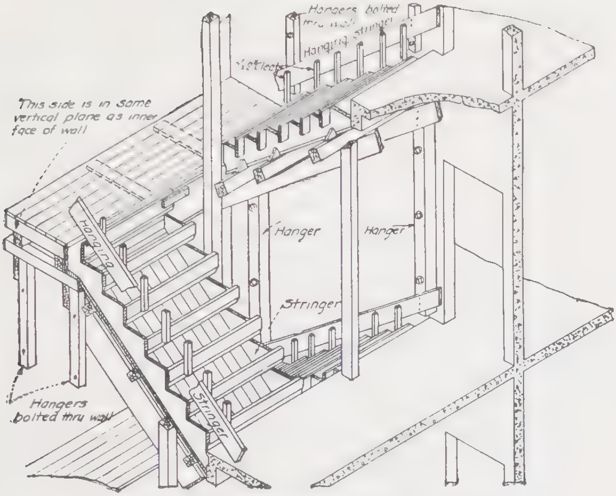


Fig. 141.—Details of stairway formwork.

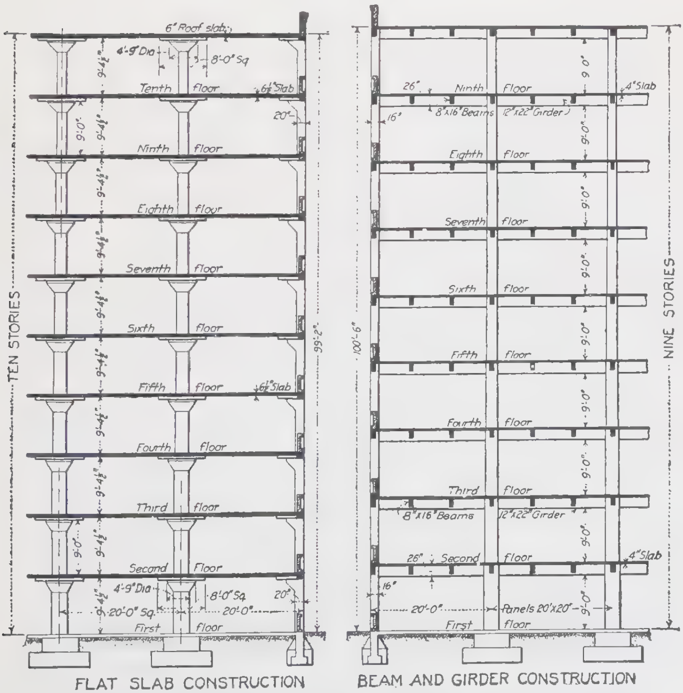


Fig. 142.—Cross sections of reinforced concrete buildings.

The concrete mixes used are invariably given in the plans and specifications. Mixes are usually proportioned to give a 28-day unit compressive strength of 2000 lb. per sq. in. or greater.

Columns are usually poured up to the bottom of the column capital and allowed to set 24 hr. before pouring the capital and floor slab. Whenever practicable, the column capitals and floor slabs and beams for any one floor should be poured in a single operation.

Forms should not be removed too soon, especially in cold weather. In general, the beam and floor-slab forms should be designed and built so that they may be removed without disturbing some of the props or shores which support the beams and slabs. Props should not be removed until it is certain that the concrete has hardened and attained enough strength easily to carry the loads placed upon it.

After the forms are removed, all fins and other projections should be removed, porous places cut out and patched when necessary, and the exposed concrete surfaces finished as required in the plans and specifications.

In most commercial and factory buildings, a cement floor finish is usually applied integral with the floor slab. In some instances, the cement floor finish is applied after the floor slab has hardened. Some other types of finish commonly used are terrazzo, tile, asphalt, linoleum, brick, steel plates (for trucking aisles), wood block set in asphalt, and various types of wood floors. Tile floors are commonly used in entrances, corridors, lobbies, vestibules, and toilets. Asphalt floors are suitable where waterproof floors are desired. Brick and wood block floors are suitable where heavy trucking occurs. Finished wood floors of oak, maple, or birch are often desired. Sleepers (about 2 × 3 in. in size and placed 16-in. on centers) are set on, and anchored to the floor slab. A layer of waterproof building paper is placed on top of the sleepers, and then the finished flooring is laid. Sometimes the space between the sleepers is filled with lean cinder concrete. Floor coverings, such as linoleum, are suitable for offices, corridors, schoolrooms, etc.

Various types of roofings have been used for reinforced concrete buildings. A cement-finish roof surface is satisfactory when absolute dryness is not required. Cement roof finishes tend to

crack in time, and thus cause small leaks. An asphalt coating, using asphalt with a high melting point, gives fairly satisfactory service, but must be renewed every year or so. The same is true of special roof paints. A built-up pitch and gravel roof, like the Barrett Specification Roof, is widely used on reinforced concrete buildings and gives satisfactory service. A built-up asphalt roofing (layers of asphalt and rag or asbestos felt) gives satisfactory service, when properly constructed. Clay tile roofings are used in cases where certain architectural effects are desired.

Walls in reinforced concrete buildings may be of concrete, brick, or clay tile covered with cement plaster. Concrete walls are usually preferred for the basement, and brick for the exterior walls of the other stories.

Partitions in the building may be constructed of reinforced concrete, brick, clay tile, gypsum tile, metal lath and plaster, wood lath and plaster, plaster board, wood, or various combinations of the materials mentioned as desired.

Other work in a reinforced concrete building, such as heating, plumbing, electric wiring, glass and glazing, roofing and flashing, painting, etc., is usually let as separate or subcontracts. This work must be considered when preparing estimates for the complete building. It is customary to secure separate bids for each of the items mentioned.

Problems.—*a.* Observe the construction of a reinforced concrete building noting all things of interest. If time permits, separate studies may be made of the excavation, concreting plant, forms and forming, bending and placing reinforcing steel, concreting, removal of forms, and surface finishing.

b. Secure a copy of the plans and specifications of a small reinforced concrete building, and prepare a complete estimate of the plant, materials, labor, and cost.

c. In addition to the preceding problem, design the plant layout and prepare work schedules and progress charts for constructing the building.

JOB 104. CONSTRUCTION OF REINFORCED CONCRETE SLAB AND GIRDER BRIDGES

Simple reinforced concrete slab and girder bridges and their abutments may be built in one of the following ways: (1) the abutments and bridge may be cast as a monolithic structure; (2) the abutments may be constructed first and the bridge cast in

place on the abutments; or (3) the abutments may be built on the job and bridge cast in a convenient place, and later hauled to the job and placed on the abutments. The first method has been used for bridges of short spans; the second method for bridges of all spans; and the third method in instances where it is not desirable to interrupt or detour traffic for more than a short time, as in the construction of a railroad slab or girder bridge over a highway.

The estimates of materials, labor, and costs may be prepared according to the principles of Sec. IV.

The staking out of the bridge and its abutments should be done by a competent engineer.

The excavation for the abutments should then be made, using a cofferdam and pumps, if necessary. If required, piles should be driven to support the abutments. Then the forms for the abutments are erected, the reinforcing steel placed and secured, and the concrete poured. Care should be taken to insure that the proportioning, mixing, and placing of the concrete conform to the specification requirements. After the concrete in the abutments has hardened sufficiently, the forms may be removed, and the surface of the concrete cleaned, fins and projections removed, porous places cut out and patched, and exposed surfaces finished as required.

The forms for the bridge proper are now constructed, the steel placed and secured in position and the concrete poured. The size of the average bridge is nearly always such that the entire bridge may be poured in one operation. It is usually advisable to start pouring at both ends and finish in the middle of the span, though some prefer to start pouring in the center and finish at the ends. After the concrete has hardened (not less than about 28 days even in warm weather) the forms may be removed and the surface cleaned and finished as required.

When the abutments and bridge are cast as a monolithic structure, the forms for the entire structure are built at one time. Concrete is poured in both abutments simultaneously. When the abutment forms are filled, the concrete is placed in the bridge forms, beginning at the abutments and ending in the center of the bridge. If all of the concreting cannot be completed at one operation, the time interval should occur between the pouring

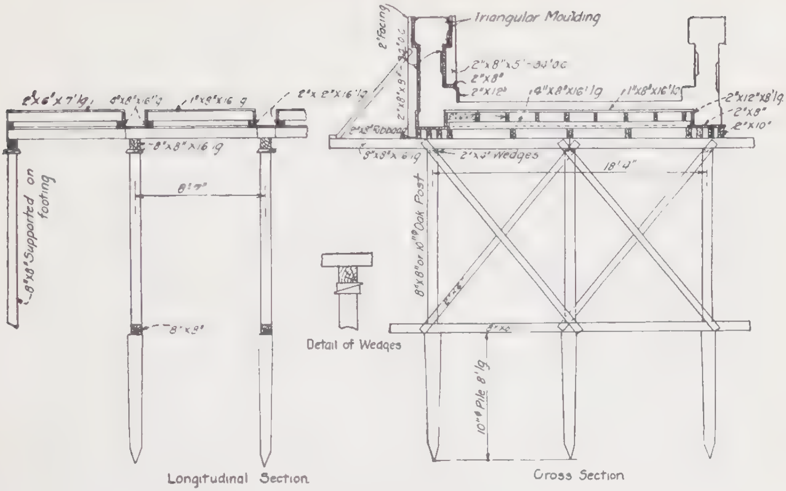


FIG. 143.—Formwork for through concrete bridge of 60 ft. span and 16 ft. roadway.

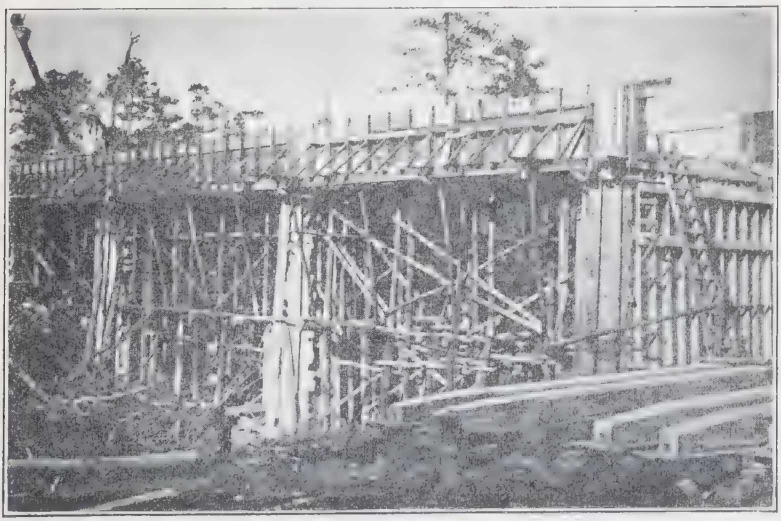


FIG. 144.—Formwork for multiple-span through girder bridge.

of the abutments and the pouring of the bridge. When pouring is resumed after a time interval, care must be taken to secure a good bond between the old and the new concrete.

Illustrations of forms for small slab and girder bridges are shown in Figs. 143, 144, and 145.

Some camber should be provided to improve the appearance of slab and girder bridges. About 1/20 inch per ft. of span length is sufficient. This would mean 1 in. for a 40-ft. span.

The proportions of the concrete mix for the abutments and the bridge are invariably given in the plans and specifications.

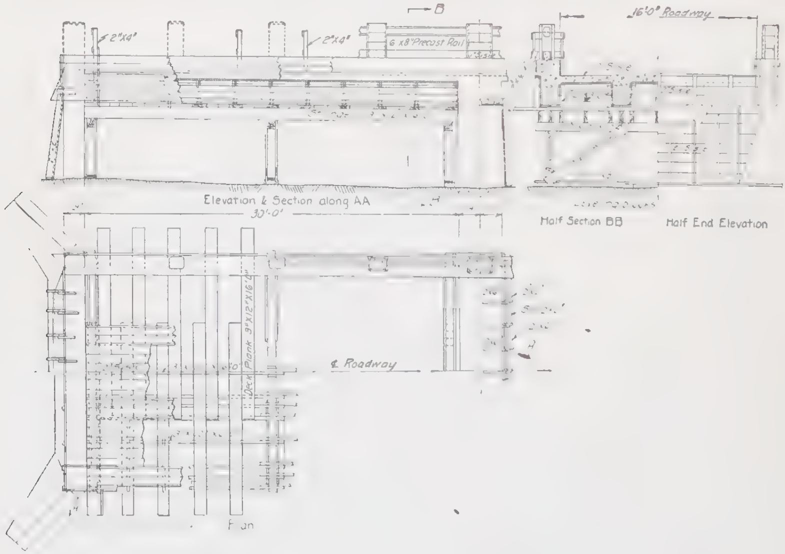


FIG. 145.—Forms and falsework for a deck girder highway bridge.

In general, leaner mixes than a 1:2½:5 for abutments, and a 1:2:4 for bridges, or mixes giving a 28-day unit compressive strength less than about 2000 lb. per sq. in. should not be used.

The concreting plant used will depend upon the amount of concrete to be poured and upon what the contractor has available for the work. The size of the mixer may vary from a two-bag to a six-bag mixer. One contractor may use runways and carts or barrows, while another may have towers chutes, and spouts.

Problems.—Inspect the construction of a slab or girder bridge and note details regarding the size of bridge and abutments, the construction of the

form work, the placing of the reinforcing steel, the concreting plant, the proportions of the concrete mixes used, the time required for pouring, the removal of forms, the surface finishing, and any other information of importance. Use sketches when these will aid in describing the work.

JOB 105. CONSTRUCTION OF REINFORCED CONCRETE ARCH BRIDGES

The construction of a reinforced concrete arch bridge is divided into several parts such as: the construction of the piers and abutments; the erection of the centering and arch formwork; the placing of the steel reinforcement; the pouring of the concrete, the removal of the forms and centering; and the finishing of the concrete surfaces.

The staking out of the arch bridge should be done by a competent engineer.

The estimates of materials, labor, and costs may be prepared according to the principles given in Sec. IV.

The details of construction of the piers or abutments will vary greatly on different jobs. In some instances, the excavation, formwork, and concreting can all be completed without interference from water. In other instances, cofferdams and pumps may be needed to keep out the water while the bridge foundations are built. Piling is usually required under the piers and abutments, unless good rock can be found at a suitable depth. At the present time, most of the bridge foundations are built of reinforced concrete resting on solid rock or piles.

The centering for a concrete arch is the falsework used to support the forms for the concrete of the arch. This falsework is usually constructed of wood, though steel centering frames are sometimes used. Steel centering may not be economical, unless there are several spans of equal dimensions so that the centering can be used several times.

Trestle centering is commonly used for small arches. The arch forms are supported on transverse caps, which, in turn, are supported by posts or piles sway braced and line girted, as in an ordinary trestle. Figures 147 and 148 illustrate this type of centering. Note the location and size of wedges used for removing the centering, after the concrete has hardened.

In truss centering, a truss forms, or is used to support, the falsework for the arch. The truss is supported at each end. The

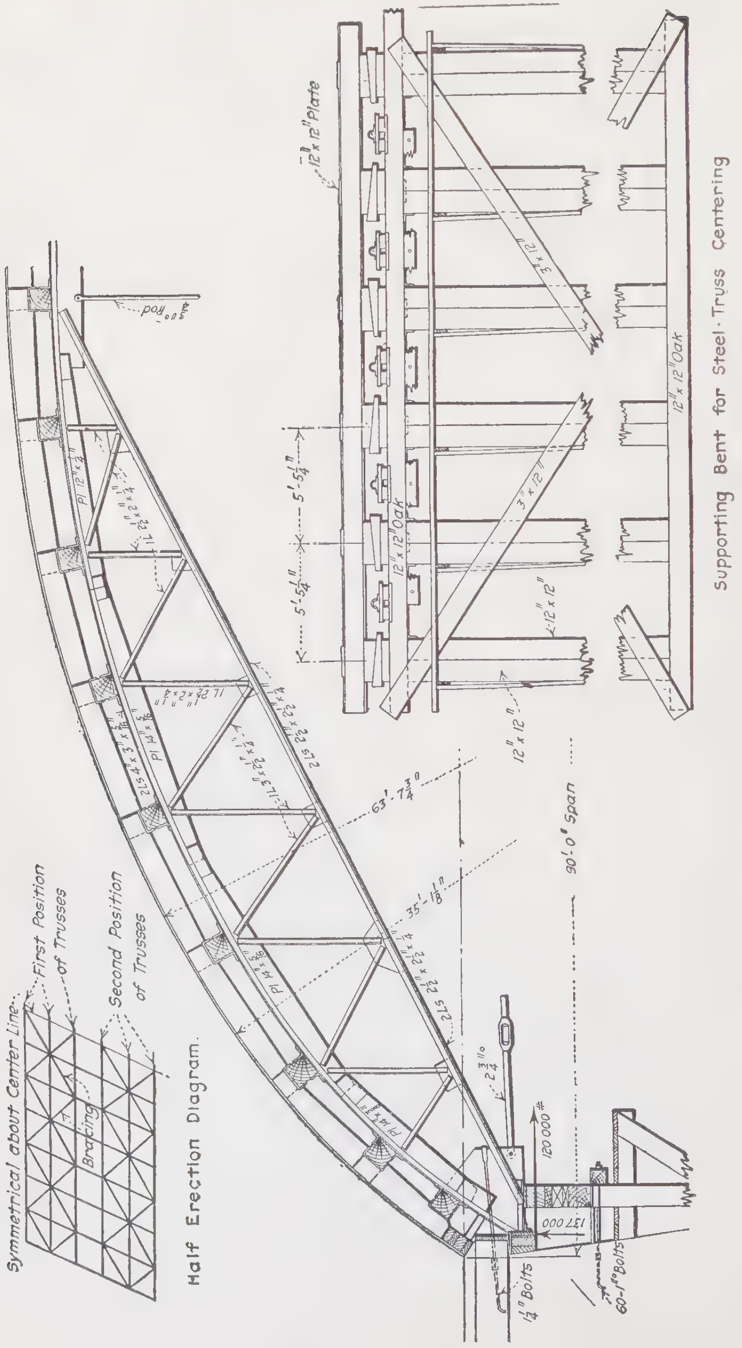


FIG. 146.—Steel centering for Atherton Avenue bridge, Pittsburgh, Pa.

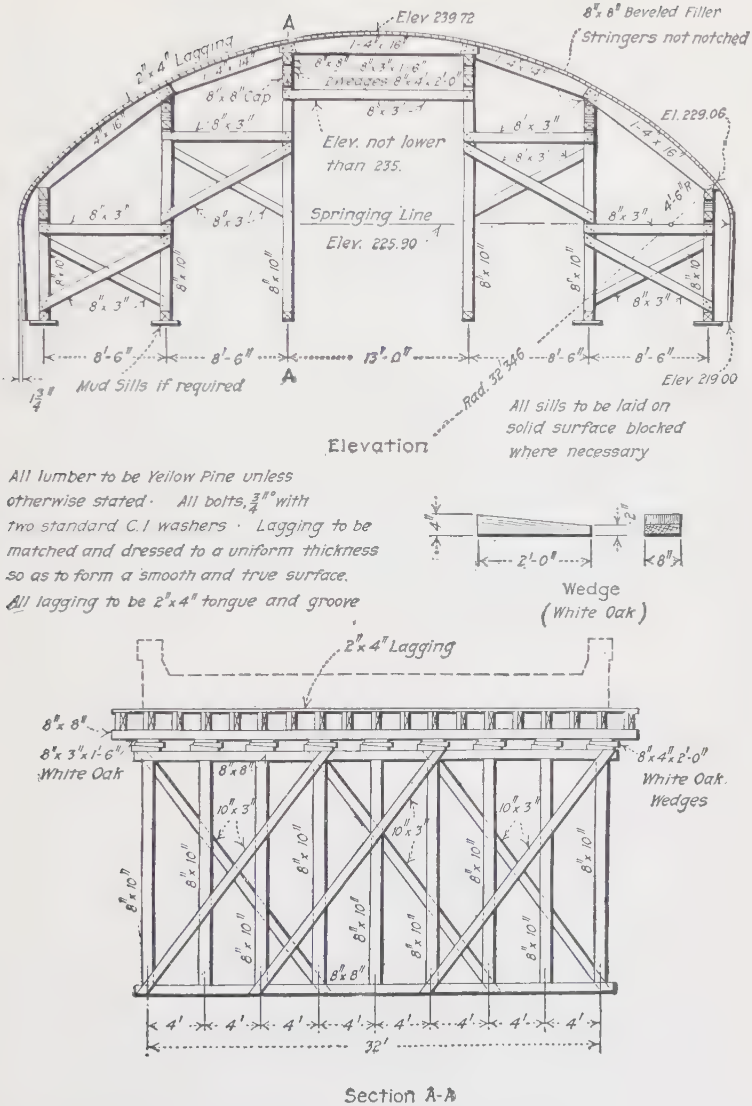


FIG. 147.—Details of arch centers for Center Street bridge, Phillipsburg, N. J.

forms for the arch are supported by short bents, which rest on the upper panel points of the truss.

Fig. 148.—Centering for Oswego Arch, Clackamas County, Oregon. Trestle type of rib centering.

When it is not permitted to have trestles or trusses underneath the arch forms, these forms may be supported by suspension cables, as shown in Fig. 149. The main cables run over towers and are anchored on shore.

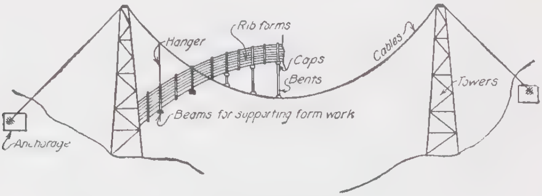


Fig. 149.—Suspended centering.

In erecting arch centers, allowance should be made for camber and for shrinkage and settlement of the centering. The camber is usually computed and added to the grade elevations on the plans, so that the plan elevations give the needed camber. In

addition to the camber, the elevations shown on the plans should be increased to care for shrinkage and settlement of the centering under the load. The amount to provide for this will depend on such things as the load, type of centering, size of members, and the method of support.

The lagging for panel arches is generally placed on longitudinal beams or joists supported at the falsework panel points. These

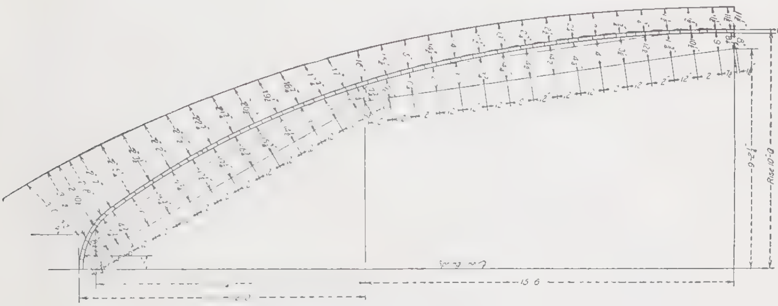


Fig. 150.—Curved lagging beams for barrel arch centering.

curved beams are cut to the true curve of the arch intrados (underside of the arch), and may be laid off either from the arch radii in a loft or yard, or as shown in Fig. 150.

After the centering and forms for the arch are erected, the reinforcing steel should be bent, placed, and secured in position as directed in the plans and specifications.

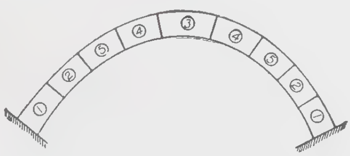


Fig. 151.—Sequence of pouring arch ring.

The concreting plant used will vary from a 2- or 3-bag mixer, with runways and carts, to a 5- or 6-bag mixer with tower, chutes, spouts, etc., depending on the size of the job and the contractor's equipment available.

Small concrete arches (with spans less than 80 ft.) are usually poured in one operation. The pouring must be done in such a

manner as to load the centering evenly and symmetrically. The simplest way is to start at both springing lines simultaneously, and to finish at the crown.

When the arch is of such size that the pouring cannot be completed in one operation, because of the shrinkage stresses and of the length of time required, such spans may be poured in longitudinal sections or by the "voussoir" method. The voussoir method is better than the longitudinal section method.

In the voussoir method, the arching is divided into sections about as shown in Fig. 151, and these are poured in sequence according to the numbering of the sections. With this method of pouring, the concrete in the arch rib cannot take any load as an arch until after the last section has been placed. Hence, any slight settlement or shrinkage of the centering will not cause the green concrete to be loaded.

The centering for concrete arches should not be removed until the concrete has hardened enough to carry the loads. A time of about 4 weeks is required in warm weather, and a longer time is desirable and often necessary in cold weather. The centering should be released very gradually. The crown should be released first, and then the two flanks simultaneously. It is a good plan at first to just start all of the wedges, and then to remove the wedges in order as directed. In a series of arches, all centers between abutments or piers should be lowered simultaneously.

After the removal of the forms, all fins and projections should be removed and all porous places cut out and repaired. Surface finishing, of the kind required in the plans and specifications, may now be done.

Problems.—Inspect the construction of a concrete arch, noting details in regard to the construction of piers and abutments, arch centering and forms, placing of reinforcing steel, pouring of concrete, removal of centering, and surface finishing. Note the general dimensions of the arch and any other data of importance. Use sketches as an aid in describing any of the construction work.

JOB 106. MANUFACTURE OF CONCRETE BLOCK OR BRICK

The essential parts of a modern concrete products plant are about as follows:

A storage space for cement, fine and coarse aggregates. Cement must be stored in a weatherproof building, and it is advis-

able to store aggregates where they will be partially or wholly protected from the weather, especially in winter time.

A building for housing the machinery and making or manufacturing the concrete masonry units. This building houses the mixers and casting machines and molds.

A building for the accelerated curing of the concrete products, if such methods are used.

A storage space for the concrete products, where they can complete their curing or aging before being shipped.

Of course, a plentiful supply of good aggregates and water, as well as shipping facilities, are also essential.

Large plants give much study to the quality of the aggregates, the proportions and consistency of the mix, the methods of weighing and measuring the materials, the methods of mixing and molding, methods of curing, labor-saving machinery, all-year work, economical layout of the plant, as well as other questions involving the procuring of the raw materials, the manufacture of the concrete products, and the marketing of manufactured articles.

Refer to Job 31 and Appendix 11 for further information in regard to concrete block and brick.

Problems.—*a.* Visit a concrete products manufacturing plant and observe the following: plant layout (a sketch of this will help), methods of receiving and storing materials, kinds of products, proportions of mixes, consistency, kinds of machines used for mixing and molding, weighing and measuring devices, labor-saving machinery in general, methods of curing, storage of manufactured products, and shipping facilities.

b. If a concrete block or brick machine is available, mix and mold about 100 units as directed by the instructor. It may be necessary to mix and mold a few samples, first, in order to get the proper consistency of the mix and to understand the operation of the machine. The quantities of materials required should be first estimated, the materials procured, the labor gang organized, and the concrete block or brick made. If a machine is not available, some simple wooden molds (preferably gang molds) can be constructed for some concrete brick, and a number of brick made by the wet cast method. Care must be taken, during the curing period, to keep the new block and brick moist, so that they will not dry out too rapidly.

JOB 107. LAYING CONCRETE BLOCK WALLS

The blocks used for concrete walls should be those capable of passing the standard specifications for Concrete Building Block

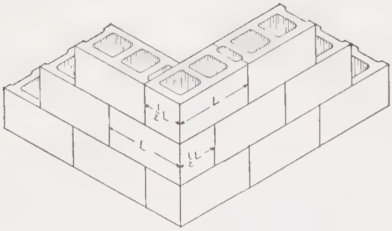


FIG. 152.

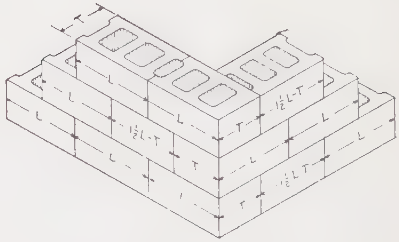


FIG. 156.

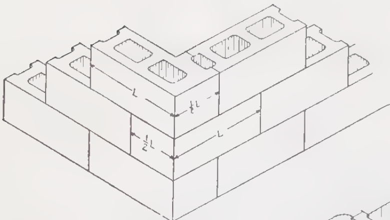


FIG. 153.

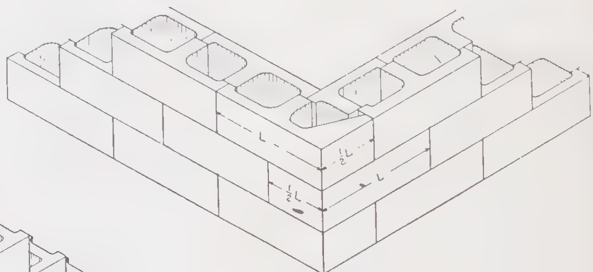


FIG. 157.

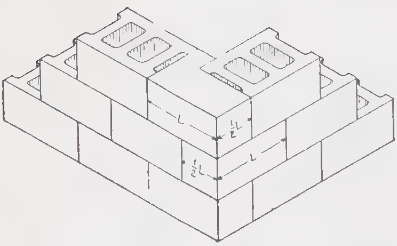


FIG. 154.

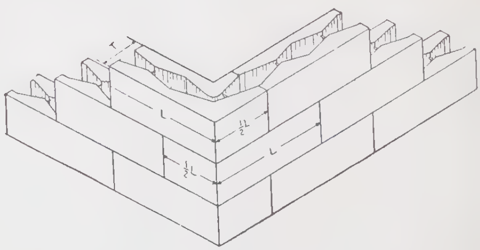


FIG. 158.

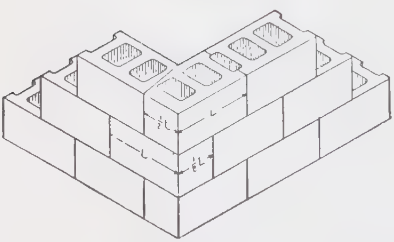


FIG. 155.

FIGS. 152–158.—Methods of laying concrete block walls.

(Appendix 11). The block may be either "load bearing" or "non-load bearing," depending on whether the wall is to support a load or not.

The mortar in concrete block masonry has three functions to perform, namely: (1) to form a bed or cushion to take up any inequalities in the block surface, and to distribute the pressure uniformly; (2) to bind the wall into a solid mass; and (3) to fill the spaces and voids between the blocks and keep out the water.

The mortar used should be a portland cement mortar of a 1:1, a 1:1½, or a 1:2 mix by volume of portland cement and sand for load-bearing block, and 1:3 mix for non-load-bearing block. The addition of lime to the mortar for load-bearing block, up to 10 lb. of lime per sack of cement, makes the mortar more plastic and workable. Some masons prefer a 1:1:6 mix by volume of cement, lime, and sand for non-load-bearing block.

A mortar batch should be of such size that the entire batch will be used within 30 min. after the mixing water is added. Retempered mortar should not be used.

The sand used for the mortar should be clean, durable, uncoated, and well graded. No particle of sand should be longer than half the thickness of the mortar joint. For ⅜-in. mortar joints, all sand used in the mortar should pass a No. 8 sieve, and not more than 5 per cent should pass a No. 100 seive.

The thickness of mortar joints in most concrete block masonry is ⅜ in., though variations from ¼ in. to ½ in. are common.

The following principles apply to the laying of concrete block:

1. All block should be thoroughly wet before laying, so that they will not absorb the water from the mortar. This wetting is important, but it is often neglected.

2. The block should be laid in a truly horizontal position except in special cases.

3. The top edge of the block should be laid to a stretched string.

4. The block masonry should be built in courses perpendicular to the pressure it is to bear.

5. The block in each course should break joints with those in the courses immediately above and below so as to provide a good longitudinal bond.

6. Sufficient transverse bond should be provided when necessary.

7. All spaces between the bearing parts of the block should be filled with mortar.

8. In laying the block, a layer of mortar should be spread uniformly over the bearing surfaces of the last course of block.

9. The block should be pressed firmly into this mortar so that some of the mortar will be squeezed out.

10. The vertical joints should be filled with mortar between the adjacent surfaces of the blocks.

11. When blocks are designed to provide a continuous air space in the wall, the block and mortar should be so placed that there will not be a continuity of concrete and mortar from the outside to the inside surface of the wall.

12. The masonry must be tested frequently with a mason's level and plumb to see that the courses are level and that the wall is plumb.

When laying concrete block walls, the corners are usually first built up for two or three courses, and strings are stretched from corner to corner (as in brick masonry) to aid in the proper laying of the block in the courses.

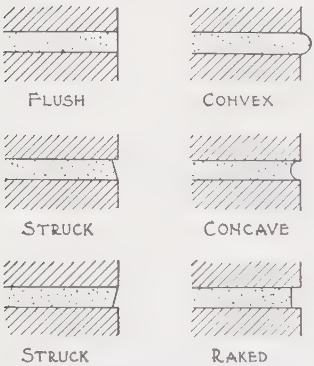


FIG. 159.—Methods of pointing joints of concrete block walls.

The joints in concrete block wall may be finished in a variety of ways. Figure 159 shows several of the more common methods of pointing.

After the wall has been built and the joints pointed, it should be cleaned by brushing or scrubbing. When necessary, the wall may be washed with a dilute solution of commercial hydrochloric acid and water. The wall should afterward be thoroughly rinsed with fresh water to remove all traces of the acid.

Problems.—*a.* Observe the construction of a concrete block wall, noting the size and kind of block, proportions of mortar, thickness of mortar joints, method of pointing, laborers used and the duties of each, time required for laying the wall, and any items of importance and interest. Compute the number of blocks laid per mason per 8-hr. day. How many helpers are there per mason?

b. Construct a concrete block wall as directed by the instructor. First estimate the number of blocks required, the amount of cement and sand needed for the mortar, and the labor hours required. Then procure the block and mortar material and construct the wall, being careful to do good work rather than fast work. Compare the actual quantities used with those previously estimated.

SECTION VII

APPENDICES

APPENDIX 1

STANDARD SPECIFICATIONS AND TESTS

FOR

PORTLAND CEMENT

American Society for Testing Materials

Serial Designation: C 9–21

These specifications and tests are issued under the fixed designation C 9; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

ADOPTED, 1904; REVISED, 1908, 1909, 1916, 1920 (EFFECTIVE JAN. 1, 1921)

These specifications were approved Mar. 31, 1922, as "American Standard" by the American Engineering Standards Committee

SPECIFICATIONS

1. Definition. Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

I. CHEMICAL PROPERTIES

2. Chemical Limits. The following limits shall not be exceeded:

Loss on ignition, per cent	4.00
Insoluble residue, per cent	0.85
Sulfuric anhydride (SO_3), per cent	2.00
Magnesia (MgO), per cent	5.00

II. PHYSICAL PROPERTIES

3. Specific Gravity. The specific gravity of cement shall be not less than 3.10 (3.07 for white portland cement). Should the test of cement as received fall below this requirement, a second test may be made upon an

ignited sample. The specific gravity test will not be made unless specifically ordered.

4. Fineness. The residue on a standard No. 200 sieve shall not exceed 22 per cent by weight.

5. Soundness. A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

6. Time of Setting. The cement shall not develop initial set in less than 45 min. when the Vicat needle is used, or 60 min. when the Gillmore needle is used. Final set shall be attained within 10 hr.

7. Tensile Strength. The average tensile strength in pounds per square inch of not less than three standard mortar briquettes (see Sec. 50) composed of 1 part cement and 3 parts standard sand, by weight, shall be equal to, or higher than, the following:

Age at test, days	Storage of briquettes	Tensile strength, pounds per square inch
7	1 day in moist air, 6 days in water.......	200
28	1 day in moist air, 27 days in water......	300

8. The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

III. PACKAGES, MARKING AND STORAGE

9. Packages and Marking. The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. A bag shall contain 94 lb. net. A barrel shall contain 376 lb. net.

10. Storage. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

IV. INSPECTION

11. Inspection. Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test, and at least 31 days shall be allowed for the completion of the 28-day test. The cement shall be tested in accordance with the methods hereinafter prescribed. The 28-day test shall be waived only when specifically so ordered.

V. REJECTION

12. Rejection. The cement may be rejected if it fails to meet any of the requirements of these specifications.

13. Cement shall not be rejected on account of failure to meet the fineness requirement if, upon retest after drying at 100°C. for 1 hr., it meets this requirement.

14. Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter.

15. Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing fifty packages taken at random, is less than that specified, the entire shipment may be rejected.

TESTS

VI. SAMPLING

16. Number of Samples. Tests may be made on individual or composite samples as may be ordered. Each test sample should weigh at least 8 lb.

17. (*a*) *Individual Sample.*—If sampled in cars, one test sample shall be taken from each 50 bbl. or fraction thereof. If sampled in bins, one sample shall be taken from each 100 bbl.

(*b*) *Composite Sample.*—If sampled in cars, one sample shall be taken from one sack in each forty sacks (or 1 bbl. in each 10 bbl.) and combined to form one test sample. If sampled in bins or warehouses, one test sample shall represent not more than 200 bbl.

18. Method of Sampling. Cement may be sampled at the mill by any of the following methods that may be practicable, as ordered:

(*a*) *From the Conveyor Delivering to the Bin.*—At least 8 lb. of cement shall be taken from approximately each 100 bbl. passing over the conveyor.

(*b*) *From Filled Bins by Means of Proper Sampling Tubes.*—Tubes inserted vertically may be used for sampling cement to a maximum depth of 10 ft. Tubes inserted horizontally may be used where the construction of the bin permits. Samples shall be taken from points well distributed over the face of the bin.

(*c*) *From Filled Bins at Points of Discharge.*—Sufficient cement shall be drawn from the discharge openings to obtain samples representative of the cement contained in the bin, as determined by the appearance at the discharge openings of indicators placed on the surface of the cement directly above these openings before drawing of the cement is started.

19. Treatment of Sample. Samples preferably shall be shipped and stored in air-tight containers. Samples shall be passed through a sieve having 20 meshes per lin. in. in order thoroughly to mix the sample, break up lumps, and remove foreign materials.

VII. CHEMICAL ANALYSIS

Loss on Ignition

20. Method. One gram of cement shall be heated in a weighed covered platinum crucible, of 20 to 25 c.c. capacity, as follows, using either method (*a*) or (*b*) as ordered:

(*a*) The crucible shall be placed in a hole in an asbestos board, clamped horizontally so that about three-fifths of the crucible projects below, and blasted at a full red heat for 15 min. with an inclined flame; the loss in weight shall be checked by a second blasting for 5 min. Care shall be taken to wipe off particles of asbestos that may adhere to the crucible when withdrawn from the hole in the board. Greater neatness and shortening of the time of heating are secured by making a hole to fit the crucible in a circular disk of sheet platinum and placing this disk over a somewhat larger hole in an asbestos board.

(*b*) The crucible shall be placed in a muffle at any temperature between 900 and 1000°C. for 15 min., and the loss in weight shall be checked by a second heating for 5 min.

21. Permissible Variation. A permissible variation of 0.25 will be allowed, and all results in excess of the specified limit, but within this permissible variation, shall be reported as 4 per cent.

Insoluble Residue

22. Method. To a 1-g. sample of cement shall be added 10 c.c. of water and 5 c.c. of concentrated hydrochloric acid; the liquid shall be warmed until effervescence ceases. The solution shall be diluted to 50 c.c. and digested on a steam bath or hot plate until it is evident that decomposition of the cement is complete. The residue shall be filtered, washed with cold water, and the filter paper and contents digested in about 30 c.c. of a 5 per cent solution of sodium carbonate, the liquid being held at a temperature just short of boiling for 15 min. The remaining residue shall be filtered, washed with cold water, then with a few drops of hot hydrochloric acid, 1:9, and finally with hot water, and then ignited at a red heat and weighed as the insoluble residue.

23. Permissible Variation. A permissible variation of 0.15 will be allowed, and all results in excess of the specified limit, but within this permissible variation, shall be reported as 0.85 per cent.

Sulfuric Anhydride

24. Method. One gram of the cement shall be dissolved in 5 c.c. of concentrated hydrochloric acid diluted with 5 c.c. of water, with gentle warming; when solution is complete, 40 c.c. of water shall be added, the solution filtered, and the residue washed thoroughly with water. The solution shall be diluted to 250 c.c., heated to boiling, and 10 c.c. of a hot 10 per cent solution of barium chloride shall be added slowly, drop by drop, from a pipette and the boiling continued until the precipitate is well formed. The solution shall be digested on the steam bath until the precipitate has settled. The precipitate shall be filtered, washed, and the paper and contents placed in a weighed platinum crucible and the paper slowly charred and consumed without flaming. The barium sulfate shall then be ignited and weighed. The weight obtained multiplied by 34.3 gives the percentage of sulfuric anhydride. The acid filtrate obtained in the determination of the insoluble residue may be used for the estimation of sulfuric anhydride, instead of using a separate sample.

25. Permissible Variation. A permissible variation of 0.10 will be allowed, and all results in excess of the specified limit, but within this permissible variation, shall be reported as 2 per cent.

MAGNESIA

26. Method. To 0.5 g. of the cement in an evaporating dish shall be added 10 c.c. of water to prevent lumping and then 10 c.c. of concentrated hydrochloric acid. The liquid shall be gently heated and agitated until attack is complete. The solution shall then be evaporated to complete dryness on a steam or water bath. To hasten dehydration, the residue may be heated to 150 or even 200°C. for ½ to 1 hr. The residue shall be treated with 10 c.c. of concentrated hydrochloric acid diluted with an equal amount of water. The dish shall be covered and the solution digested for 10 min. on a steam bath or water bath. The diluted solution shall be filtered and the separated silica washed thoroughly with water.[1] Five cubic centimeters of concentrated hydrochloric acid, and sufficient bromine water to precipitate any manganese which may be present, shall be added to the filtrate (about 250 c.c.). This shall be made alkaline with ammonium hydroxide, boiled until there is but a faint odor of ammonia, and the precipitated iron and aluminum hydroxides, after settling, shall be washed with hot water, once by decantation and slightly on the filter. Setting aside the filtrate, the precipitate shall be transferred by a jet of hot water to the precipitating vessel and dissolved in 10 c.c. of hot hydrochloric acid. The paper shall be extracted with acid, the solution and washings being added to the main solution. The aluminum and iron shall then be reprecipitated at boiling heat by ammonium hydroxide and bromine water in a volume of about 100 c.c., and the second precipitate shall be collected and washed on the filter used in the first instance, if this is still intact. To the combined filtrates from the hydroxides of iron and aluminum, reduced in volume if need be, 1 c.c. of ammonium hydroxide shall be added, the solution brought to boiling, 25 c.c. of a saturated solution of boiling ammonium oxalate added, and the boiling continued until the precipitated calcium oxalate has assumed a well-defined granular form. The precipitate after 1 hr. shall be filtered and washed, then with the filter shall be placed wet in a platinum crucible, and the paper burned off over a small flame of a Bunsen burner; after ignition it shall be redissolved in hydrochloric acid and the solution diluted to 100 c.c. Ammonia shall be added in slight excess, and the liquid boiled. The lime shall then be reprecipitated by ammonium oxalate, allowed to stand until settled, filtered, and washed. The combined filtrates from the calcium precipitates shall be acidified with hydrochloric acid, concentrated on the steam bath to about 150 c.c., and made slightly alkaline with ammonium hydroxide, boiled and filtered (to remove a little aluminum and iron and perhaps calcium). When cool, 10 c.c. of saturated solution of sodium-ammonium-hydrogen phosphate shall be added with constant stirring. When the crystallin ammonium-magnesium orthophosphate has formed, ammonia shall be added in moderate excess. The solution shall

[1] Since this procedure does not involve the determination of silica, a second evaporation is unnecessary.

be set aside for several hours in a cool place, filtered and washed with water containing 2.5 per cent of NH_3. The precipitate shall be dissolved in a small quantity of hot hydrochloric acid, the solution diluted to about 100 c.c., 1 c.c. of a saturated solution of sodium-ammonium-hydrogen phosphate added, and ammonia drop by drop, with constant stirring, until the precipitate is again formed as described and the ammonia is in moderate excess. The precipitate shall then be allowed to stand about 2 hr., filtered and washed as before. The paper and contents shall be placed in a weighed platinum crucible, the paper slowly charred, and the resulting carbon carefully burned off. The precipitate shall then be ignited to constant weight over a Meker burner, or a blast not strong enough to soften or melt the pyrophosphate. The weight of magnesium pyrophosphate obtained, multiplied by 72.5, gives the percentage of magnesia. The precipitate so obtained always contains some calcium and usually small quantities of iron, aluminum, and manganese as phosphates.

27. Permissible Variation. A permissible variation of 0.4 will be allowed, and all results in excess of the specified limit, but within this permissible variation, shall be reported as 5 per cent.

VIII. DETERMINATION OF SPECIFIC GRAVITY

28. Apparatus. The determination of specific gravity shall be made with a standardized Le Chatelier apparatus which conforms to the requirements illustrated in Fig. 1. This apparatus is standardized by the U. S. Bureau of Standards. Kerosene free from water, or benzine not lighter than 62° Baumé, shall be used in making this determination.

29. Method. The flask shall be filled with either of these liquids to a point on the stem between zero and 1 c.c., and 64 g. of cement, of the same temperature as the liquid, shall be slowly introduced, taking care that the cement does not adhere to the inside of the flask above the liquid and to free the cement from air by rolling the flask in an inclined position. After all the cement is introduced, the level of the liquid will rise to some division of the graduated neck; the difference between readings is the volume displaced by 64 g. of the cement.

The specific gravity shall then be obtained from the formula:

$$\text{Specific gravity} = \frac{\text{Weight of cement (g.)}}{\text{Displaced volume (c.c.)}}$$

30. The flask, during the operation, shall be kept immersed in water, in order to avoid variations in the temperature of the liquid in the flask, which shall not exceed 0.5°C. The results of repeated tests should agree within 0.01.

31. The determination of specific gravity shall be made on the cement as received; if it falls below 3.10, a second determination shall be made after igniting the sample as described in Sec. 20.

IX. DETERMINATION OF FINENESS

32. Apparatus. Wire cloth for standard sieves for cement shall be woven (not twilled) from brass, bronze, or other suitable wire, and mounted without distortion on frames not less than 1½ in. below the top of the frame. The

sieve frames shall be circular, approximately 8 in. in diameter, and may be provided with a pan and cover.

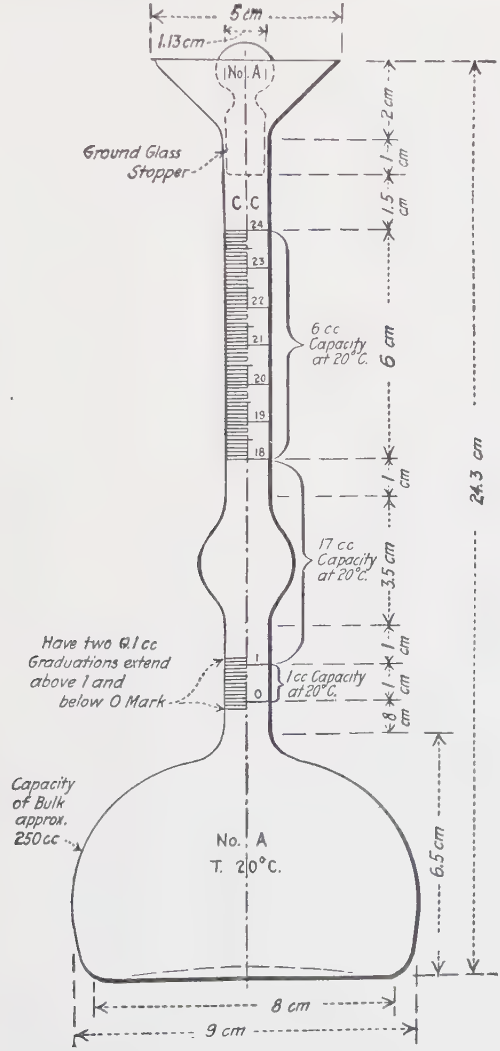


Fig. 1.—Le Chatelier apparatus.

33. A standard No. 200 sieve is one having nominally an 0.0029-in. opening and 200 wires per inch standardized by the U. S. Bureau of Standards, and conforming to the following requirements:

The No. 200 sieve should have 200 wires per in., and the number of wires in any whole inch shall not be outside the limits of 192 to 208. No opening between adjacent parallel wires shall be more than 0.0050 in. in width. The diameter of the wire should be 0.0021 in. and the average diameter shall not be outside the limits 0.0019 to 0.0023 in. The value of the sieve, as determined by sieving tests made in conformity with the standard specifications for these tests on a standardized cement, which gives a residue of 25 to 20 per cent on the No. 200 sieve, or on other similarly graded material, shall not show a variation of more than 1.5 per cent above or below the standards maintained at the Bureau of Standards.

34. Method. The test shall be made with 50 g. of cement. The sieve shall be thoroughly clean and dry. The cement shall be placed on the No. 200 sieve, with pan and cover attached, if desired. The sieve shall be held in one hand in a slightly inclined position, so that the sample will be well distributed over the sieve, at the same time gently striking the side about one hundred and fifty times per minute against the palm of the other hand on the up stroke. The sieve shall be turned every twenty-five strokes about one-sixth of a revolution in the same direction. The operation shall continue until not more than 0.05 g. passes through in 1 min. of continuous sieving. The fineness shall be determined from the weight of the residue on the sieve expressed as a percentage of the weight of the original sample.

35. Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method described in Sec. 34.

X. MIXING CEMENT PASTES AND MORTARS

36. Method. The quantity of dry material to be mixed at one time shall not exceed 1000 g. nor be less than 500 g. The proportions of cement, or cement and sand, shall be stated by weight in grams of the dry materials; the quantity of water shall be expressed in cubic centimeters (1 c.c. of water = 1 g.). The dry materials shall be weighed, placed upon a non-absorbent surface, thoroughly mixed dry if sand is used, and a crater formed in the center, into which the proper percentage of clean water shall be poured; the material on the outer edge shall be turned into the crater by the aid of a trowel. After an interval of $\frac{1}{2}$ min. for the absorption of the water, the operation shall be completed by continuous, vigorous mixing, squeezing and kneading with the hands for at least 1 min.[1] During the operation of mixing, the hands should be protected by rubber gloves.

37. The temperature of the room and the mixing water shall be maintained as nearly as practicable at 21°C. (70°F.).

[1] In order to secure uniformity in the results of tests for the time of setting and tensile strength, the manner of mixing above described should be carefully followed. At least 1 min. is necessary to obtain the desired plasticity, which is not appreciably affected by continuing the mixing for several minutes. The exact time necessary is dependent upon the personal equation of the operator. The error in mixing should be on the side of overmixing.

XI. NORMAL CONSISTENCY

38. Apparatus. The Vicat apparatus consists of a frame A (Fig. 2) bearing a movable rod B, weighing 300 g., one end, C, being 1 cm. in diameter for a distance of 6 cm., the other having a removable needle D, 1 mm. in diameter, 6 cm. long. The rod is reversible, and can be held in any desired position by a screw E, and has midway between the ends a mark F which moves under a scale (graduated to millimeters) attached to the frame A.

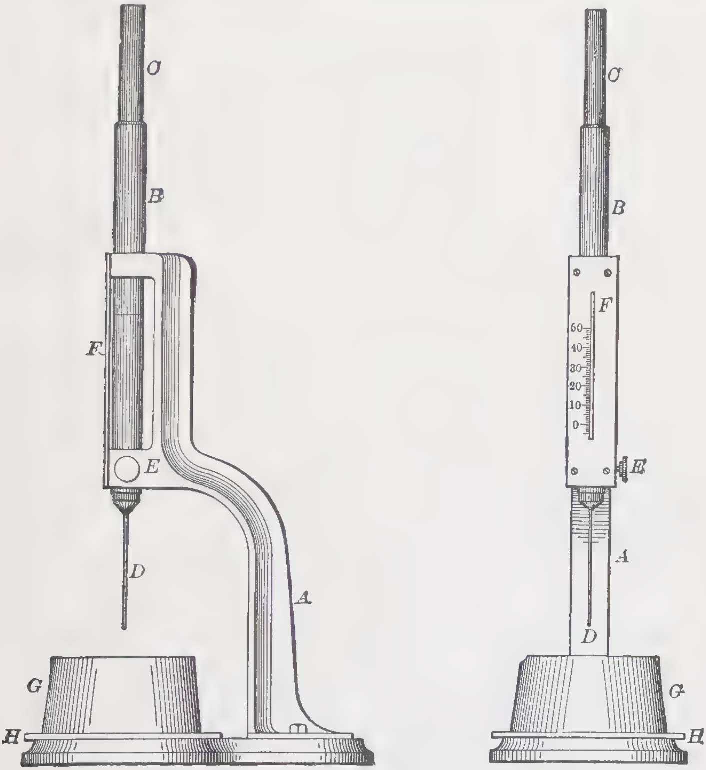


Fig. 2.—Vicat apparatus.

The paste is held in a conical, hard-rubber ring G, 7 cm. in diameter at the base, 4 cm. high, resting on a glass plate H about 10 cm. square.

39. Method. In making the determination, 500 g. of cement, with a measured quantity of water, shall be kneaded into a paste, as described in Sec. 36, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained about 6 in. apart; the ball resting in the palm of one hand shall be pressed into the larger end of the rubber ring held in the other hand, completely filling

the ring with paste; the excess at the larger end shall then be removed by a single movement of the palm of the hand; the ring shall then be placed on its larger end on a glass plate, and the excess paste at the smaller end sliced off at the top of the ring by a single oblique stroke of a trowel held at a slight angle with the top of the ring. During these operations, care shall be taken not to compress the paste. The paste confined in the ring, resting on the plate, shall be placed under the rod, the larger end of which shall be brought in contact with the surface of the paste; the scale shall then be read, and the rod quickly released. The paste shall be of normal consistency when the rod settles to a point 10 mm. below the original surface in $\frac{1}{2}$ min. after being released. The apparatus shall be free from all vibrations during the test. Trial pastes shall be made with varying percentages of water until the normal consistency is obtained. The amount of water required shall be expressed in percentage by weight of the dry cement.

40. The consistency of standard mortar shall depend on the amount of water required to produce a paste of normal consistency from the same sample of cement. Having determined the normal consistency of the sample, the consistency of standard mortar made from the same sample shall be as indicated in Table 1, the values being in percentage of the combined dry weights of the cement and standard sand.

XII. DETERMINATION OF SOUNDNESS[1]

41. Apparatus. A steam apparatus, which can be maintained at a temperature between 98 and 100°C., or one similar to that shown in Fig. 3, is recommended. The capacity of this apparatus may be increased by using a rack for holding the pats in a vertical or inclined position.

42. Method. A pat from cement paste of normal consistency about 3 in. in diameter, $\frac{1}{2}$ in. thick at the center, and tapering to a thin edge, shall be made on clean glass plates about 4 in. square, and stored in moist air for 24 hr. In molding the pat, the cement paste shall first be flattened on the glass and the pat when formed by drawing the trowel from the outer edge toward the center.

43. The pat shall then be placed in an atmosphere of steam at a temperature between 98 and 100°C. upon a suitable support 1 in. above boiling water for 5 hr.

44. Should the pat leave the plate, distortion may be detected best with a straight edge applied to the surface which was in contact with the plate.

XIII. DETERMINATION OF TIME OF SETTING

45. The following are alternate methods, either of which may be used as ordered:

[1] Unsoundness is usually manifested by change in volume which causes distortion, cracking, checking or disintegration.

Pats improperly made or exposed to drying may develop what are known as shrinkage cracks within the first 24 hr. and are not an indication of unsoundness. These conditions are illustrated in Fig. 4.

The failure of the pats to remain on the glass or the cracking of the glass to which the pats are attached does not necessarily indicate unsoundness.

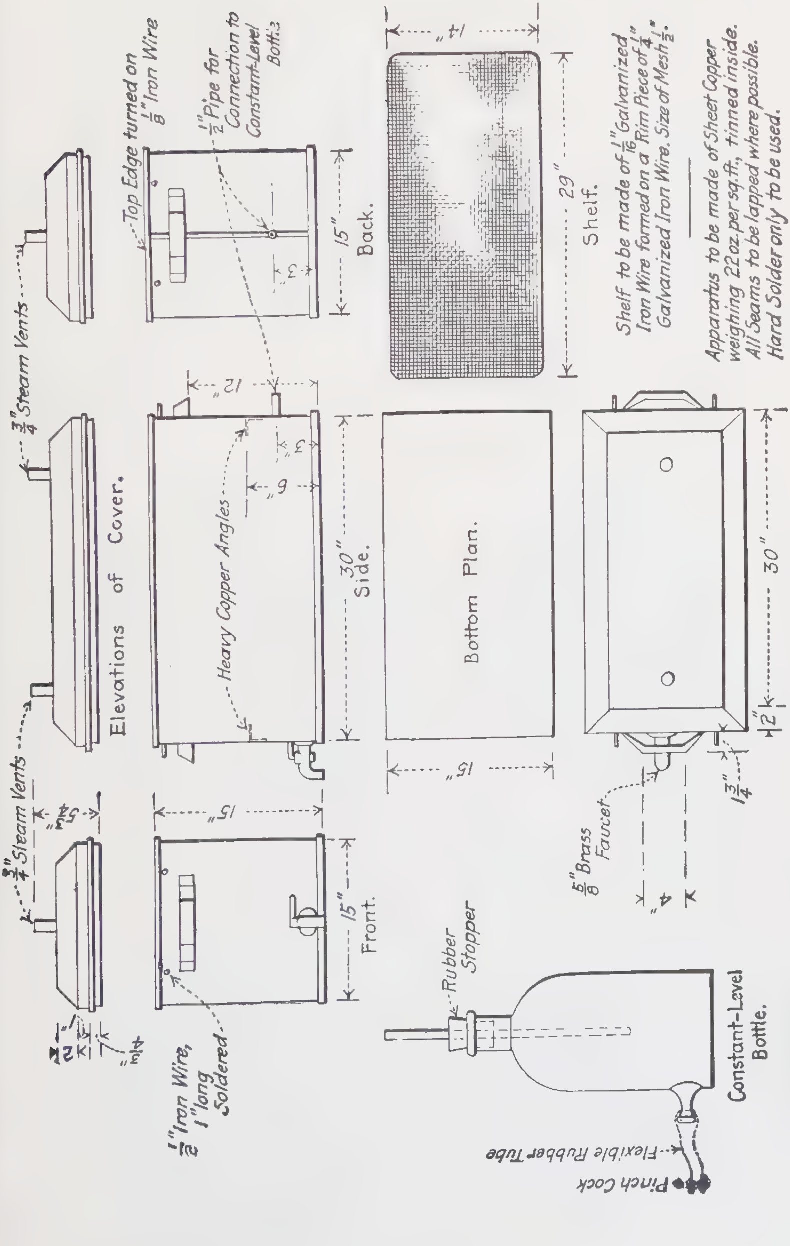


FIG. 3.—Apparatus for making soundness test of cement.

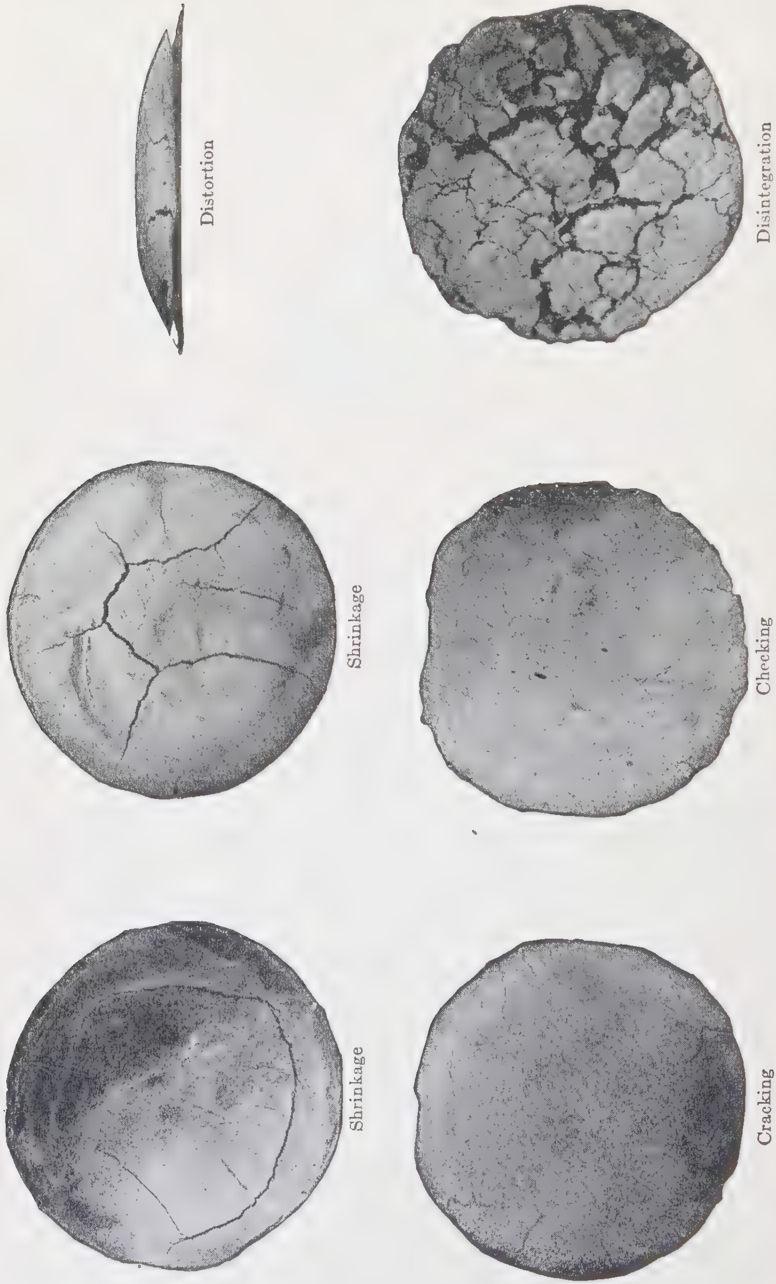


FIG. 4.—Typical failures in soundness test.

46. Vicat Apparatus. The time of setting shall be determined with the Vicat apparatus described in Sec. 38. (See Fig. 2.)

TABLE I.—PERCENTAGE OF WATER FOR STANDARD MORTARS

Percentage of water for neat cement paste of normal consistency	Percentage of water for one cement, three standard Ottawa sand	Percentage of water for neat cement paste of normal consistency	Percentage of water for one cement, three standard Ottawa sand
15	9.0	23	10.3
16	9.2	24	10.5
17	9.3	25	10.7
18	9.5	26	10.8
19	9.7	27	11.0
20	9.8	28	11.2
21	10.0	29	11.3
22	10.2	30	11.5

47. Vicat Method. A paste of normal consistency shall be molded in the hard-rubber ring *G* as described in Sec. 39, and placed under the rod *B*, the smaller end of which shall then be carefully brought in contact with the surface of the paste, and the rod quickly released. The initial set shall be said to have occurred when the needle ceases to pass a point 5 mm. above the glass plate in ½ min. after being released; and the final set, when the needle does not sink visibly into the paste. The test pieces shall be kept in moist air during the test. This may be accomplished by placing them on a rack over water contained in a pan and covered by a damp cloth, kept from contact with them by means of a wire screen; or they may be stored in a moist closet. Care shall be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point may increase the penetration. The time of setting is affected not only by the percentage and temperature of the water used and the amount of kneading the paste receives, but by the temperature and humidity of the air, and its determination is therefore only approximate.

48. Gillmore Needles. The time of setting shall be determined by the Gillmore needles. The Gillmore needles should preferably be mounted as shown in Fig. 5 (*b*).

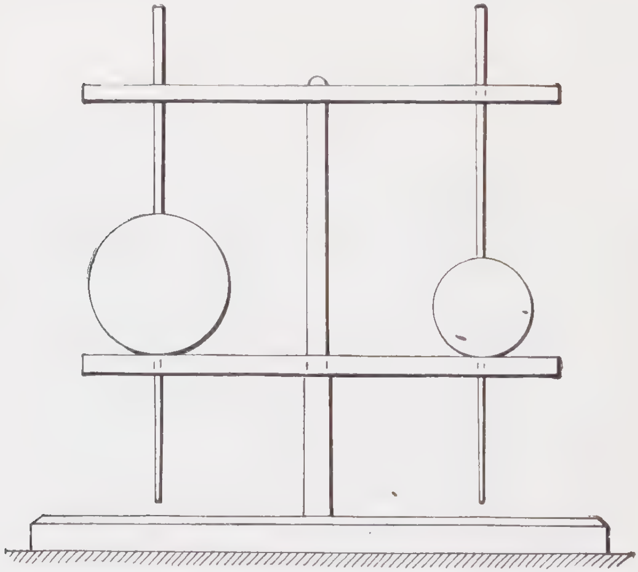
49. Gillmore Method. The time of setting shall be determined as follows: A pat of neat cement paste about 3 in. in diameter and ½ in. in thickness with a flat top (Fig. 5 (*a*)) mixed to a normal consistency, shall be kept in moist air at a temperature maintained as nearly as practicable at 21°C. (70°F.). The cement shall be considered to have acquired its initial set when the pat will bear, without appreciable indentation, the Gillmore needle, $\frac{1}{12}$ in. in diameter, loaded to weigh ¼ lb. The final set has been acquired when the pat will bear without appreciable indentation, the Gill-

more needle $\frac{1}{24}$ in. in diameter, loaded to weigh 1 lb. In making the test, the needles shall be held in a vertical position and applied lightly to the surface of the pat.

XIV. TENSION TESTS

50. Form of Test Piece. The form of test piece shown in Fig. 6 shall be used. The molds shall be made of non-corroding metal and have sufficient material in the sides to prevent spreading during molding. Gang molds

(a) Pat with top surface flattened for determining time by Gillmore method.



(b) Gillmore needles.

FIG. 5.

when used shall be of the type shown in Fig. 7. Molds shall be wiped with an oily cloth before using.

51. Standard Sand. The sand to be used shall be natural sand from Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve. This sand may be obtained from the Ottawa Silica Co., at a cost of 3 cts. per lb., f.o.b. cars, Ottawa, Ill.

52. This sand, having passed the No. 20 sieve, shall be considered standard when not more than 5 g. passes the No. 30 sieve after 1 min. continuous sieving of a 500-g. sample.

53. The sieves shall conform to the following specifications:

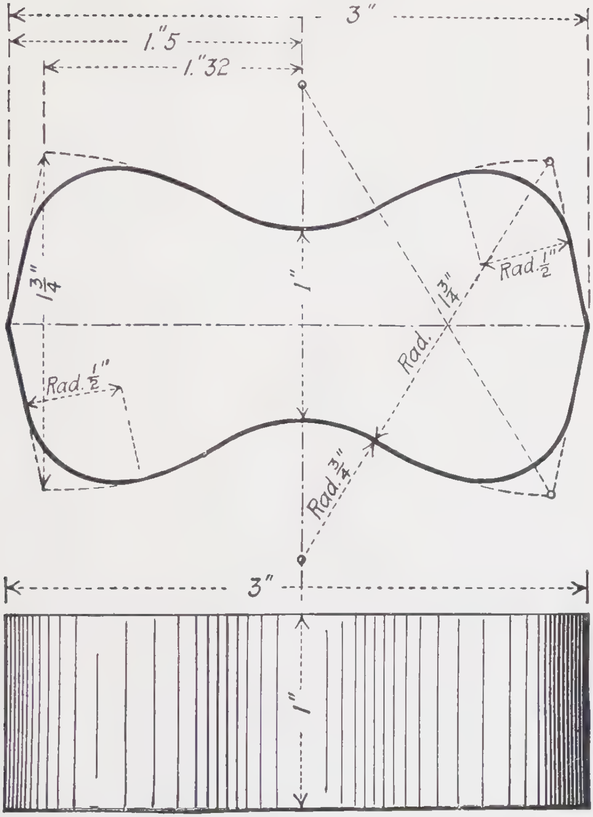


Fig. 6.—Details for briquette.

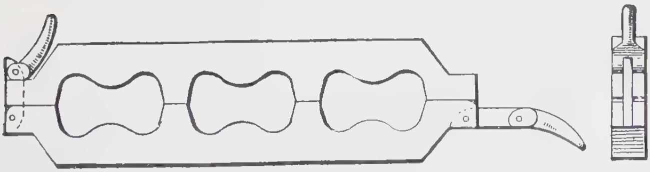


Fig. 7.—Gang mold.

The No. 20 sieve shall have between 19.5 and 20.5 wires per whole inch of the warp wires and between 19 and 21 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0165 in. and the average diameter shall not be outside the limits of 0.0160 and 0.0170 in.

The No. 30 sieve shall have between 29.5 and 30.5 wires per whole inch of the warp wires and between 28.5 and 31.5 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0110 in. and the average diameter shall not be outside the limits 0.0105 to 0.0115 in.

54. Molding. Immediately after mixing, the standard mortar shall be placed in the molds, pressed in firmly with the thumbs and smoothed off with a trowel without ramming. Additional mortar shall be heaped above the mold and smoothed off with a trowel; the trowel shall be drawn over the mold in such a manner as to exert a moderate pressure on the material. The mold shall then be turned over and the operation of heaping, thumbing, and smoothing off repeated.

55. Testing. Tests shall be made with any standard machine. The briquettes shall be tested as soon as they are removed from the water. The bearing surfaces of the clips and briquettes shall be free from grains of sand or dirt. The briqeuttes shall be carefully centered and the load applied continuously at the rate of 600 lb. per min.

56. Testing machines should be frequently calibrated in order to determine their accuracy.

57. Faulty Briquettes. Briquettes that are manifestly faulty, or that give strengths differing more than 15 per cent from the average value of all test pieces made from the same sample and broken at the same period, shall not be considered in determining the tensile strength.

XV. STORAGE OF TEST PIECES

58. Apparatus. The moist closet may consist of a soapstone, slate, or concrete box, or a wooden box lined with metal. If a wooden box is used, the interior should be covered with felt or broad wicking kept wet. The bottom of the moist closet should be covered with water. The interior of the closet should be provided with non-abosrbent shelves on which to place the test pieces, the shelves being so arranged that they may be withdrawn readily.

59. Methods. Unless otherwise specified, all test pieces, immediately after molding, shall be placed in the moist closet for from 20 to 24 hr.

60. The briquettes shall be kept in molds on glass plates in the moist closet for at least 20 hr. After from 20 to 24 hr. in moist air the briquettes shall be immersed in clean water in storage tanks of non-corroding material.

61. The air and water shall be maintained as nearly as practicable at a temperature of 21°C. (70°F.).

APPENDIX 2

STANDARD METHOD OF TEST

FOR

UNIT WEIGHT OF AGGREGATE FOR CONCRETE

American Society for Testing Materials

Serial Designation: C 29–21

This method is issued under the fixed designation C 29; the final number indicates the year of original adoption as standard, or, in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1920; ADOPTED, 1921

This method was approved May 29, 1923, as "Tentative American Standard" by the American Engineering Standards Committee

1. The unit weight of fine, coarse, or mixed aggregates for concrete shall be determined by the following method:

2. Apparatus. (*a*) The apparatus required consists of a cylindrical metal measure, a tamping rod, and a scale or balance, sensitive to 0.5 per cent of the weight of the sample to be weighed.

(*b*) *Measures.*—The measure shall be of metal, preferably machined to accurate dimensions on the inside, cylindrical in form, water-tight, and of sufficient rigidity to retain its form under rough usage, with top and bottom true and even, and preferably provided with handles.

The measure shall be of 1/10-, 1/2-, or 1-cu. ft. capacity, depending on the maximum diameter of the coarsest particles in the aggregate, and shall be of the following dimensions:

Capacity, cubic feet	Inside diameter, inches	Inside height, inches	Minimum thickness of metal, U. S. Gage	Diameter of largest particles of aggregate, inches
1/10	6	6.10	No. 11	Under 1/2
1/2	10	11.00	No. 8	Under 1 1/2
1	14	11.23	No. 5	Over 1 1/2

(*c*) *Tamping Rod.*—The tamping rod shall be a straight metal rod 3/4 in. in diameter and 18 in. long, with one end tapered for a distance of 1 in. to a blunt bullet-shaped point.

3. Calibrating the Measure. The measure shall be calibrated by accurately determining the weight of water at 16.7°C. (62°F.) required to fill it. The factor for any unit shall be obtained by dividing the unit weight of water at 16.7°C. (62°F.)[1] by the weight of water at 16.7°C. (62°F.) required to fill the measure.

4. The sample of aggregate shall be room dry and thoroughly mixed.

5. Method. (*a*) The measure shall be filled one-third full and the top leveled off with the fingers. The mass shall be tamped with the pointed end of the tamping rod twenty-five times, evenly distributed over the surface. The measure shall be filled two-thirds full and again tamped twenty-five times as before. The measure shall then be filled to overflowing, tamped twenty-five times, and the surplus aggregate struck off, using the tamping rod as a straightedge.

In tamping the first layer the rod should not be permitted forcibly to strike the bottom of the measure. In tamping the second and final layers, only enough force to cause the tamping rod to penetrate the last layer of aggregate placed in the measure should be used. No effort should be made to fill holes left by the rod when the aggregate is damp.

(*b*) The net weight of the aggregate in the measure shall be determined. The unit weight of the aggregate shall then be obtained by multiplying the net weight of the aggregate by the factor found as described in Sec. 3.

6. Accuracy. Results with the same sample should check within 1 per cent.

APPENDIX 3

STANDARD METHOD OF TEST

FOR

SIEVE ANALYSIS OF AGGREGATES FOR CONCRETE

American Society for Testing Materials

Serial Designation: C 41–24

This method is issued under the fixed designation C 41; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

ISSUED AS TENTATIVE, 1921; ADOPTED, 1922; REVISED, 1924

1. Sampling. A representative test sample of the aggregate shall be selected by quartering or by use of a sampler, which after drying will give not less than the following:

(*a*) Fine aggregate, 500 g.

(*b*) Coarse aggregate, or a mixture of fine and coarse aggregates, weight in grams, 3000 times size of largest sieve required, measured in inches.

[1] The unit weight of water at 16.7°C. (62°F.) is 62.355 lb. per cu. ft.

TABLE I

Sieve number[1] or size in inches	Sieve opening		Wire diameter		Tolerance, per cent			
	Mm.	In.	Mm.	In.	Average opening	Wire diameter		Maximum opening
						Under	Over	
No. 100	0.149	0.0059	0.102	0.0040	6	15	35	40
No. 50	0.297	0.0117	0.188	0.0074	6	15	35	40
No. 30	0.59	0.0232	0.33	0.0130	5	15	30	25
No 16	1.19	0.0469	0.54	0.0213	3	15	30	10
No. 8	2.38	0.0937	0.84	0.0331	3	15	30	10
No. 4	4.76	0.187	1.27	0.050	3	15	30	10
⅜ in.	9.5	0.375	2.33	0.092	3	10	10	10
¾ in.	19.0	0.75	3.42	0.135	3	10	10	10
1 in.	25.4	1.00	4.12	0.162	3	10	10	10
1½ in.	38.0	1.50	4.50	0.177	3	10	10	10
2 in.	50.8	2.00	4.88	0.192	3	10	10	10
3 in.	76.0	3.00	6.3	0.25	3	10	10	10

[1] The requirements for sieves No. 100 to No. 4 conform to the requirements of the U. S Standard Sieve Series as given in U. S. Bureau of Standards *Letter Circular* No. 74. The liberal tolerances will permit the use of certain sieves which do not exactly correspond to the numbers given in table.

2. Treatment of Sample. The sample shall be dried at not over 110°C. (230°F.) to constant weight.

3. Sieves. (*a*) The sieves shall be of square mesh wire cloth and shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sifting.

(*b*) The size of wire and sieve openings shall be as given in Table I.

4. Procedure. (*a*) The sample shall be separated into a series of sizes by means of the sieves specified in Sec. 3. Sifting shall be continued until not more than 1 per cent by weight of the sample passes any sieve during 1 min.

(*b*) Each size shall be weighed on a balance or scale which is sensitive to $\frac{1}{1000}$ of the weight of the test sample.

(*c*) The percentage by weight of the total sample which is finer *than each* of the sieves shall be computed.

5. Report. (*a*) The percentages in sieve analysis shall be reported to the nearest whole number.

(*b*) If more than 15 per cent of a fine aggregate is coarser than the No. 4 sieve, or more than 15 per cent of a coarse aggregate is finer than the No. 4 sieve, the sieve analysis of the portions finer and coarser than this sieve shall be reported separately.

APPENDIX 4

TENTATIVE METHOD OF DECANTATION TEST

FOR

SAND AND OTHER FINE AGGREGATES

American Society for Testing Materials

Serial Designation: D 136–22 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1922

1. Scope. This method of test covers the determination of the total quantity of silt, loam, clay, etc., in sand and other fine aggregates.[1]

2. Apparatus. The pan or vessel to be used in the determination shall be approximately 9 in. (230 mm.) in diameter and not less than 4 in. (102 mm.) in depth.

3. Treatment of Sample. The sample must contain sufficient moisture to prevent segregation and shall be thoroughly mixed. A representative portion of the sample sufficient to yield approximately 500 g. of dried material, shall then be dried to a constant weight at a temperature not exceeding 110°C. (230°F.).

4. Procedure. The dried material shall be placed in the pan and sufficient water added to cover the sample (about 225 c.c.). The contents of the pan shall be agitated vigorously for 15 sec., and then be allowed to settle for 15 sec., after which the water shall be poured off, care being taken not to pour off any sand. This operation shall be repeated until the wash water is clear. As a precaution, the wash water shall be poured through a 200-mesh sieve and any material retained thereon returned to the washed sample. The washed sand shall be dried to a constant weight at a temperature not exceeding 110°C. (230°F.) and weighed.

5. Calculation of Results. The results shall be calculated from the formula:

Percentage of silt, clay, loam, etc. =

$$\frac{\text{original dry weight} - \text{weight after washing}}{\text{original dry weight}} \times 100$$

6. Check Determination. When check determinations are desired, the wash water shall be evaporated to dryness, the residue weighed, and the percentage calculated from the formula:

$$\text{Percentage of silt, loam, clay, etc.} = \frac{\text{weight of residue}}{\text{original dry weight}} \times 100$$

[1] This determination of the percentage of silt, clay, loam, etc., will include all water-soluble material present, the percentage of which may be determined separately if desired.

APPENDIX 5

STANDARD METHOD OF TEST

FOR

ORGANIC IMPURITIES IN SANDS FOR CONCRETE

American Society for Testing Materials

Serial Designation: C 40–22

This method is issued under the fixed designation C 40; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

Proposed as Tentative, 1921; Adopted, 1922

This method was approved May 29, 1923, as "Tentative American Standard" by the American Engineering Standards Committee.

1. Scope. The test herein specified is an approximate test for the presence of injurious organic compounds in natural sands for cement mortar or concrete. The principal value of the test is in furnishing a warning that further tests of the sand are necessary before they be used in concrete. Sands which produce a color in the sodium hydroxide solution darker than the standard color should be subjected to strength tests in mortar or concrete before use.

2. Sample. (*a*) A representative test sample of sand of about 1 lb. shall be obtained by quartering or by the use of a sampler.

Procedure. (*b*) A 12-oz. graduated glass prescription bottle shall be filled to the 4½-oz. mark with the sand to be tested.

(*c*) A 3 per cent solution of sodium hydroxide ($NaOH$) in water shall be added until the volume of sand and liquid after shaking gives a total value of 7 liquid oz.

(*d*) The bottle shall be stoppered and shaken thoroughly and then allowed to stand for 24 hr.

(*e*) A standard color solution shall be prepared by adding 2.5 c.c. of a 2 per cent solution of tannic acid in 10 per cent alcohol to 22.5 c.c. of a 3 per cent sodium hydroxide solution. This shall be placed in a 12-oz. prescription bottle, stoppered and allowed to stand for 24 hr., then 25 c.c. of water added.

Color Value. (*f*) The color of the clear liquid above the sand shall be compared with the standard color solution prepared as in Paragraph (*e*) or with a glass of color similar to the standard solution.

3. Solutions darker in color than the standard color have a "color value" higher than 250 parts per million in terms of tannic acid.

APPENDIX 6

PROPORTIONS[1] FOR CONCRETE OF GIVEN COMPRESSIVE STRENGTH AT 28 DAYS

From the 1924 Report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete.

The table gives the proportions in which portland cement and a wide range in sizes of fine and coarse aggregates should be mixed to obtain concrete of compressive strengths ranging from 1500 to 3000 lb. per sq. in. at 28 days. Proportions are given for concrete of four different consistencies.

The purpose of the table is twofold:

(1) To furnish a guide in the selection of mixtures to be used in preliminary investigations of the strength of concrete from given materials.

(2) To indicate proportions which may be expected to produce concrete of a given strength under average conditions where control tests are not made.

If the proportions to be used in the work are selected from the table without preliminary tests of the materials, and control tests are not made during the progress of the work, the mixtures in bold-face type shall be used.

The use of this table as a guide in the selection of concrete mixtures is based on the following:

(1) Concrete shall be plastic;

(2) Aggregates shall be clean and structurally sound;

(3) Aggregates shall be graded between the sizes indicated;

(4) Cement shall conform to the requirements of the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9–21) of the American Society for Testing Materials. (Appendix 1.)

The plasticity of the concrete shall be determined by the slump test carried out in accordance with the Tentative Method of Test for Consistency of Portland-Cement Concrete (Serial Designation: D 138–25 T) of the American Society for Testing Materials. (Appendix 7.)

Apply the following rules in determining the size assigned to a given aggregate:

(1) Not less than 15 per cent shall be retained between the sieve which is considered the maximum size[2] and the next smaller sieve.

(2) Not more than 15 per cent of a coarse aggregate shall be finer than the sieve considered as the minimum size.[2]

(3) Only the sieve sizes given in the table shall be considered in applying Rules 1 and 2.

[1] Based on the 28-day compressive strengths of 6- by 12-in. cylinders, made and stored in accordance with the Standard Methods of Making Compression Tests of Concrete (Serial Designation: C 39–25) of the American Society for Testing Materials. (Appendix 8.)

[2] For example: a graded sand with 16 per cent retained on the No. 8 sieve would fall in the 0-No. 4 size; if 14 per cent or less were retained, the sand would fall in the 0-No. 8 size. A coarse aggregate having 16 per cent coarser than 2-in. sieve would be considered as 3-in. aggregate.

(4) Sieve analysis shall be made in accordance with the Standard Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C 41–24) of the American Society for Testing Materials. (Appendix 3.)

Proportions may be interpolated for concrete strengths, aggregate sizes and consistencies not covered by the table or determined by test.

Proportions for 1500 Lb. per Sq. In. Concrete

Proportions are expressed by volume as follows: Portland Cement: Fine Aggregate: Coarse Aggregate.

Thus 1:2.6:4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate, and 4.6 parts by volume of coarse aggregate.

Size of coarse aggregate	Slump, inches	Size of fine aggregate				
		0-No. 28	0-No. 14	0-No. 8	0-No. 4	0-⅜ in.
None	½ to 1	1:2.8	1:3.2	1:3.8	1:4.4	1:5.1
	3 to 4	1:2.4	1:2.8	1:3.3	1:3.8	1:4.5
	6 to 7	**1:1.9**	**1:2.2**	**1:2.6**	**1:3.0**	**1:3.6**
	8 to 10	1:1.4	1:1.6	1:1.8	1:2.1	1:2.5
No. 4 to ¾ in.	½ to 1	1:2.6:4.6	1:2.9:4.3	1:3.4:4.1	1:3.9:3.6	1:4.6:3.1
	3 to 4	1:2.3:4.0	1:2.6:3.8	1:2.9:3.6	1:3.4:3.2	1:4.1:2.8
	6 to 7	**1:1.8:3.4**	**1:2.0:3.2**	**1:2.3:3.1**	**1:2.6:2.8**	**1:3.1:2.5**
	8 to 10	1:1.1:2.5	1:1.3:2.4	1:1.5:2.4	1:1.7:2.2	1:2.1:2.0
No. 4 to 1 in.	½ to 1	1:2.4:5.3	1:2.7:5.2	1:3.1:5.0	1:3.5:4.7	1:4.3:4.3
	3 to 4	1:2.1:4.7	1:2.4:4.5	1:2.7:4.4	1:3.1:4.1	1:3.7:3.7
	6 to 7	**1:1.6:3.9**	**1:1.8:3.8**	**1:2.1:3.7**	**1:2.4:3.5**	**1:2.9:3.3**
	8 to 10	1:1.1:2.9	1:1.2:2.8	1:1.4:2.8	1:1.6:2.7	1:1.9:2.5
No. 4 to 1½ in.	½ to 1	1:2.4:6.0	1:2.7:5.9	1:3.1:5.8	1:3.5:5.4	1:4.1:5.1
	3 to 4	1:2.0:5.4	1:2.3:5.3	1:2.7:5.2	1:3.0:5.0	1:3.5:4.6
	6 to 7	**1:1.6:4.4**	**1:1.8:4.3**	**1:2.0:4.3**	**1:2.3:4.1**	**1:2.7:3.9**
	8 to 10	1:1.0:3.3	1:1.1:3.2	1:1.3:3.2	1:1.5:3.1	1:1.8:2.9
No. 4 to 2 in.	½ to 1	1:2.2:6.9	1:2.4:6.8	1:2.8:6.8	1:3.1:6.6	1:3.7:6.4
	3 to 4	1:1.8:6.2	1:2.0:6.1	1:2.4:6.1	1:2.7:6.0	1:3.1:5.7
	6 to 7	**1:1.4:5.1**	**1:1.6:5.0**	**1:1.8:5.0**	**1:2.0:5.0**	**1:2.4:4.8**
	8 to 10	1:0.9:3.8	1:1.0:3.8	1:1.1:3.8	1:1.3:3.8	1:1.5:3.7
⅜ to 1 in.	½ to 1	1:2.8:5.2	1:3.1:5.1	1:3.6:4.8	1:4.2:4.6	1:4.8:4.1
	3 to 4	1:2.4:4.5	1:2.6:4.5	1:3.1:4.3	1:3.6:4.0	1:4.1:3.6
	6 to 7	**1:1.9:3.9**	**1:2.1:3.7**	**1:2.4:3.6**	**1:2.8:3.4**	**1:3.2:3.1**
	8 to 10	1:1.3:2.8	1:1.4:2.8	1:1.6:2.7	1:1.9:2.6	1:2.2:2.4
⅜ to 1½ in.	½ to 1	1:2.8:5.8	1:3.1:5.7	1:3.5:5.5	1:4.1:5.3	1:4.7:4.9
	3 to 4	1:2.4:5.2	1:2.7:5.1	1:3.1:5.0	1:3.5:4.8	1:4.1:4.4
	6 to 7	**1:1.9:4.3**	**1:2.1:4.2**	**1:2.4:4.2**	**1:2.7:4.0**	**1:3.1:3.7**
	8 to 10	1:1.2:3.2	1:1.4:3.2	1:1.6:3.1	1:1.8:3.0	1:2.1:2.9
⅜ to 2 in.	½ to 1	1:2.7:6.6	1:3.0:6.6	1:3.4:6.5	1:3.9:6.4	1:4.4:6.0
	3 to 4	1:2.3:5.9	1:2.6:5.9	1:2.9:5.8	1:3.3:5.6	1:3.7:5.5
	6 to 7	**1:1.8:4.9**	**1:2.0:4.8**	**1:2.2:4.8**	**1:2.6:4.8**	**1:3.0:4.5**
	8 to 10	1:1.2:3.7	1:1.3:3.7	1:1.5:3.7	1:1.7:3.6	1:1.9:3.5
¾ to 1½ in.	½ to 1	1:3.2:5.4	1:3.6:5.3	1:4.1:5.1	1:4.7:4.8	1:5.3:4.4
	3 to 4	1:2.8:4.8	1:3.2:4.8	1:3.6:4.6	1:4.0:4.4	1:4.6:4.0
	6 to 7	**1:2.1:4.0**	**1:2.5:4.0**	**1:2.8:3.9**	**1:3.2:3.7**	**1:3.5:3.4**
	8 to 10	1:1.5:3.0	1:1.7:3.0	1:1.9:2.9	1:2.2:2.8	1:2.5:2.7
¾ to 2 in.	½ to 1	1:3.2:6.2	1:3.6:6.1	1:4.0:6.0	1:4.6:5.8	1:5.2:5.4
	3 to 4	1:2.8:5.5	1:3.1:5.5	1:3.5:5.4	1:3.9:5.2	1:4.5:4.9
	6 to 7	**1:2.1:4.5**	**1:2.4:4.6**	**1:2.7:4.5**	**1:3.1:4.4**	**1:3.5:4.1**
	8 to 10	1:1.4:3.4	1:1.6:3.4	1:1.8:3.4	1:2.1:3.4	1:2.4:3.3
¾ to 3 in.	½ to 1	1:3.2:7.1	1:3.6:7.1	1:4.0:7.0	1:4.6:6.9	1:5.2:6.6
	3 to 4	1:2.7:6.3	1:3.0:6.3	1:3.4:6.3	1:4.0:.62	1:4.5:5.9
	6 to 7	**1:2.1:5.1**	**1:2.4:5.2**	**1:2.7:5.2**	**1:3.1:6.1**	**1:3.5:4.9**
	8 to 10	1:1.4:3.8	1:1.6:3.9	1:1.8:3.9	1:2.1:3.9	1:2.4:3.8

Proportions for 2000 Lb. per Sq. In. Concrete

Proportions are expressed by volume as follows: Portland Cement: Fine Aggregate: Coarse Aggregate.

Thus 1:2.6:4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate, and 4.6 parts by volume of coarse aggregate.

Size of coarse aggregate	Slump, inches	Size of fine aggregate				
		0-No. 28	0-No. 14	0-No. 8	0-No. 4	0-3/8 in.
None	½ to 1	1:2.2	1:2.6	1:3.0	1:3.5	1:4.1
	3 to 4	1:1.9	1:2.2	1:2.6	1:3.0	1:3.5
	6 to 7	**1:1.5**	**1:1.7**	**1:2.0**	**1:2.3**	**1:2.7**
	8 to 10	**1:1.0**	**1:1.1**	**1:1.3**	1:1.6	1:1.8
No. 4 to ¾ in.	½ to 1	1:2.1:3.8	1:2.3:3.7	1:2.6:3.5	1:3.0:3.1	1:3.6:2.8
	3 to 4	1:1.7:3.3	1:1.9:3.2	1:2.2:3.1	1:2.6:2.8	1:3.0:2.4
	6 to 7	**1:1.3:2.7**	**1:1.4:2.6**	**1:1.7:2.5**	**1:1.9:2.3**	**1:2.3:2.1**
	8 to 10	1:0.8:1.9	1:0.9:1.9	1:1.0:1.8	1:1.2:1.7	1:1.5:1.6
No. 4 to 1 in.	½ to 1	1:1.9:4.5	1:2.2:4.3	1:2.5:4.2	1:2.8:3.9	1:3.4:3.6
	3 to 4	1:1.6:3.9	1:1.8:3.8	1:2.1:3.7	1:2.4:3.5	1:2.8:3.2
	6 to 7	**1:1.2:3.1**	**1:1.3:3.1**	**1:1.5:3.0**	**1:1.8:2.9**	**1:2.1:2.7**
	8 to 10	1:0.7:2.2	1:0.8:2.2	1:1.0:2.3	1:1.1:2.1	1:1.3:2.0
No. 4 to 1½ in.	½ to 1	1:1.9:5.0	1:2.1:4.9	1:2.4:4.9	1:2.7:4.6	1:3.2:4.4
	3 to 4	1:1.6:4.4	1:1.7:4.3	1:2.0:4.2	1:2.4:4.0	1:2.7:3.8
	6 to 7	**1:1.1:3.5**	**1:1.3:3.5**	**1:1.4:3.5**	**1:1.7:3.4**	**1:2.0:3.2**
	8 to 10	1:0.7:2.5	1:0.8:2.5	1:0.9:2.5	1:1.0:2.4	1:1.2:2.3
No. 4 to 2 in.	½ to 1	1:1.7:5.8	1:1.9:5.7	1:2.1:5.8	1:2.4:5.6	1:2.8:5.5
	3 to 4	1:1.4:5.0	1:1.5:5.0	1:1.8:5.0	1:2.0:4.9	1:2.3:4.7
	6 to 7	**1:1.0:4.1**	**1:1.1:4.1**	**1:1.2:4.1**	**1:1.4:4.1**	**1:1.7:3.9**
	8 to 10	1:0.6:2.9	1:.07:2.9	1:0.7:3.0	1:0.8:2.9	1:1.0:2.9
⅜ to 1 in.	½ to 1	1:2.2:4.4	1:2.5:4.2	1:2.8:4.1	1:3.3:3.8	1:3.8:3.4
	3 to 4	1:1.9:3.8	1:2.1:3.7	1:2.4:3.6	1:2.8:3.4	1:3.2:3.1
	6 to 7	**1:1.4:3.1**	**1:1.5:3.0**	**1:1.8:3.0**	**1:2.1:2.8**	**1:2.4:2.5**
	8 to 10	1:0.9:2.2	1:1.0:2.2	1:1.1:2.2	1:1.3:2.0	1:1.5:1.9
⅜ to 1½ in.	½ to 1	1:2.2:4.9	1:2.5:4.8	1:2.8:4.7	1:3.2:4.6	1:3.7:4.2
	3 to 4	1:1.9:4.3	1:2.1:4.2	1:2.4:4.1	1:2.7:4.0	1:3.1:3.7
	6 to 7	**1:1.4:3.5**	**1:1.5:3.4**	**1:1.7:3.4**	**1:2.0:3.3**	**1:2.3:3.1**
	8 to 10	1:0.9:2.5	1:1.0:2.5	1:1.1:2.4	1:1.3:2.4	1:1.5:2.3
⅜ to 2 in.	½ to 1	1:2.1:5.6	1:2.3:5.5	1:2.6:5.5	1:3.0:5.4	1:3.5:5.1
	3 to 4	1:1.7:4.8	1:2.0:4.8	1:2.2:4.8	1:2.5:4.7	1:2.9:4.4
	6 to 7	**1:1.3:4.0**	**1:1.4:3.9**	**1:1.6:3.9**	**1:1.8:3.9**	**1:2.1:3.8**
	8 to 10	1:0.8:2.9	1:0.9:2.9	1:1.0:2.9	1:1.2:2.9	1:1.3:2.8
¾ to 1½ in.	½ to 1	1:2.6:4.5	1:2.9:4.5	1:3.3:4.4	1:3.8:4.2	1:4.3:3.9
	3 to 4	1:2.2:3.9	1:2.5:3.9	1:2.8:3.8	1:3.2:3.6	1:3.6:3.3
	6 to 7	**1:1.6:3.2**	**1:1.8:3.2**	**1:2.1:3.1**	**1:2.4:3.0**	**1:2.7:2.8**
	8 to 10	1:1.0:2.3	1:1.2:2.3	1:1.4:2.2	1:1.6:2.2	1:1.8:2.1
¾ to 2 in.	½ to 1	1:2.5:5.2	1:2.8:5.2	1:3.2:5.1	1:3.6:5.0	1:4.1:4.7
	3 to 4	1:2.1:4.5	1:2.4:4.5	1:2.7:4.4	1:3.1:4.3	1:3.5:4.0
	6 to 7	**1:1.6:3.7**	**1:1.8:3.7**	**1:2.0:3.7**	**1:2.3:3.6**	**1:2.6:3.5**
	8 to 10	1:1.0:2.6	1:1.1:2.7	1:1.3:2.6	1:1.5:2.7	1:1.7:2.6
¾ to 3 in.	½ to 1	1:2.5:6.0	1:2.9:5.9	1:3.2:5.9	1:3.6:5.8	1:4.1:5.6
	3 to 4	1:2.1:5.1	1:2.4:5.2	1:2.7:5.2	1:3.1:5.1	1:3.5:4.9
	6 to 7	**1:1.5:4.1**	**1:1.7:4.2**	**1:2.0:4.2**	**1:2.3:4.2**	**1:2.5:4.0**
	8 to 10	1:1.0:2.9	1:1.1:3.0	1:1.3:3.0	1:1.5:3.0	1:1.7:3.0

Proportions for 2500 Lb. per Sq. In. Concrete

Proportions are expressed by volume as follows: Portland Cement: Fine Aggregate: Coarse Aggregate.

Thus 1:2.6:4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate, and 4.6 parts by volume of coarse aggregate.

Size of coarse aggregate	Slump, inches	Size of fine aggregate				
		0-No. 28	0-No. 14	0-No. 8	0-No. 4	0-3/8 in.
None	½ to 1	1:1.8	1:2.1	1:2.4	1:2.9	1:3.3
	3 to 4	1:1.5	1:1.8	1:2.1	1:2.4	1:2.8
	6 to 7	**1:1.1**	**1:1.3**	**1:1.6**	**1:1.8**	**1:2.1**
	8 to 10	1:0.7	1:0.8	1:0.9	1:1.1	1:1.3
No. 4 to ¾ in.	½ to 1	1:1.6:3.2	1:1.8:3.1	1:2.1:3.0	1:2.4:2.7	1:2.9:2.4
	3 to 4	1:1.3:2.8	1:1.5:2.7	1:1.7:2.6	1:2.0:2.4	1:2.4:2.2
	6 to 7	**1:1.0:2.2**	**1:1.1:2.2**	**1:1.3:2.1**	**1:1.5:2.0**	**1:1.8:1.8**
	8 to 10	1:0.5:1.4	1:0.6:1.4	1:0.7:1.4	1:0.8:1.4	1:1.0:1.3
No. 4 to 1 in.	½ to 1	1:1.5:3.7	1:1.7:3.7	1:2.0:3.5	1:2.2:3.4	1:2.7:3.1
	3 to 4	1:1.2:3.3	1:1.4:3.2	1:1.6:3.1	1:1.9:3.0	1:2.2:2.7
	6 to 7	**1:0.9:2.6**	**1:1.0:2.5**	**1:1.1:2.5**	**1:1.3:2.4**	**1:1.6:2.3**
	8 to 10	1:0.5:1.7	1:0.6:1.7	1:0.6:1.7	1:0.7:1.6	1:0.9:1.5
No. 4 to 1½ in.	½ to 1	1:1.4:4.2	1:1.6:4.1	1:1.9:4.1	1:2.2:4.0	1:2.5:3.8
	3 to 4	1:1.2:3.7	1:1.3:3.6	1:1.5:3.6	1:1.8:3.5	1:2.1:3.3
	6 to 7	**1:0.9:2.9**	**1:0.9:2.8**	**1:1.1:2.8**	**1:1.3:2.8**	**1:1.5:2.6**
	8 to 10	1:0.5:1.9	1:0.5:1.9	1:0.6:1.9	1:0.7:1.8	1:0.8:1.8
No. 4 to 2 in.	½ to 1	1:1.3:4.9	1:1.4:4.8	1:1.6:4.9	1:1.9:4.8	1:2.2:4.7
	3 to 4	1:1.1:4.3	1:1.2:4.2	1:1.3:4.3	1:1.6:4.2	1:1.8:4.1
	6 to 7	**1:0.7:3.3**	**1:0.8:3.3**	**1:0.9:3.4**	**1:1.1:3.3**	**1:1.2:3.3**
	8 to 10	1:0.4:2.2	1:2.4:2.2	1:0.5:2.2	1:0.6:2.2	1:0.6:2.2
⅜ to 1 in.	½ to 1	1:1.8:3.7	1:2.0:3.6	1:2.3:3.5	1:2.6:3.3	1:3.0:2.9
	3 to 4	1:1.4:3.2	1:1.6:3.1	1:1.9:2.9	1:2.2:2.9	1:2.5:2.6
	6 to 7	**1:1.0:2.5**	**1:1.2:2.5**	**1:1.3:2.4**	**1:1.6:2.3**	**1:1.8:2.2**
	8 to 10	1:0.6:1.6	1:0.7:1.6	1:0.8:1.6	1:0.9:1.6	1:1.0:1.5
⅜ to 1½ in.	½ to 1	1:1.7:4.1	1:1.9:4.1	1:2.2:4.0	1:2.5:3.9	1:2.9:3.6
	3 to 4	1:1.5:3.6	1:1.6:3.6	1:1.8:3.5	1:2.1:3.4	1:2.3:3.2
	6 to 7	**1:1.0:2.9**	**1:1.2:2.8**	**1:1.3:2.8**	**1:1.5:2.7**	**1:1.8:2.6**
	8 to 10	1:0.6:1.9	1:0.6:1.9	1:0.8:1.8	1:0.9:1.8	1:1.0:1.8
⅜ to 2 in.	½ to 1	1:1.7:4.7	1:1.8:4.7	1:2.1:4.7	1:2.4:4.6	1:2.7:4.4
	3 to 4	1:1.4:4.1	1:1.5:4.1	1:1.7:4.1	1:2.0:4.0	1:2.3:3.9
	6 to 7	**1:1.0:3.2**	**1:1.1:3.2**	**1:1.2:3.2**	**1:1.4:3.2**	**1:1.6:3.1**
	8 to 10	1:0.5:2.1	1:0.6:2.1	1:0.7:2.2	1:0.8:2.2	1:0.9:2.1
¾ to 1½ in.	½ to 1	1:2.0:3.8	1:2.3:3.8	1:2.6:3.7	1:3.0:3.6	1:3.4:3.3
	3 to 4	1:1.7:3.3	1:2.0:3.3	1:2.2:3.2	1:2.5:3.2	1:2.9:2.9
	6 to 7	**1:1.2:2.6**	**1:1.4:2.6**	**1:1.6:2.6**	**1:1.9:2.5**	**1:2.1:2.3**
	8 to 10	1:0.7:1.7	1:0.8:1.7	1:0.9:1.7	1:1.1:1.7	1:1.2:1.6
¾ to 2 in.	½ to 1	1:2.0:4.4	1:2.2:4.4	1:2.5:4.3	1:2.9:4.3	1:3.3:4.1
	3 to 4	1:1.7:3.8	1:1.9:3.8	1:2.1:3.8	1:2.5:3.7	1:2.8:3.6
	6 to 7	**1:1.2:3.0**	**1:1.4:3.0**	**1:1.5:3.0**	**1:1.8:3.0**	**1:2.0:2.8**
	8 to 10	1:0.7:2.0	1:0.8:2.0	1:0.9:2.0	1:1.0:2.0	1:1.2:2.0
¾ to 3 in.	½ to 1	1:2.0:5.0	1:2.2:5.0	1:2.5:5.0	1:2.7:5.0	1:3.2:4.7
	3 to 4	1:1.7:4.3	1:1.9:4.3	1:2.1:4.3	1:2.4:4.3	1:2.7:4.1
	6 to 7	**1:1.2:3.3**	**1:1.4:3.4**	**1:1.5:3.4**	**1:1.8:3.4**	**1:2.0:3.3**
	8 to 10	1:0.7:2.2	1:0.8:2.2	1:0.9:2.2	1:1.0:2.3	1:1.2:2.3

Proportions for 3000 Lb. per Sq. In. Concrete

Proportions are expressed by volume as follows: Portland Cement: Fine Aggregate: Coarse Aggregate.

Thus 1:2.6:4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate, and 4.6 parts by volume of coarse aggregate.

Size of coarse aggregate	Slump, inches	Size of fine aggregate				
		0-No. 28	0-No. 14	0-No. 8	0-No. 4	0-3/8 in.
None..........	½ to 1	1:1.5	1:1.7	1:2.0	1:2.3	1:2.7
	3 to 4	1:1.2	1:1.4	1:1.7	1:1.9	1:2.3
	6 to 7	**1:0.9**	**1:1.0**	**1:1.2**	**1:1.4**	**1:1.6**
	8 to 10	1:0.5	1:0.6	1:0.7	1:0.8	1:0.9
No. 4 to ¾ in..	½ to 1	1:1.3:2.7	1:1.5:2.6	1:1.7:2.5	1:1.9:2.4	1:2.3:2.1
	3 to 4	1:1.0:2.3	1:1.2:2.2	1:1.4:2.2	1:1.6:2.0	1:1.9:1.8
	6 to 7	**1:0.7:1.7**	**1:0.8:1.7**	**1:0.9:1.7**	**1:1.1:1.6**	**1:1.3:1.4**
	8 to 10	1:0.3:1.0	1:0.4:1.0	1:0.5:1.0	1:0.5:1.0	1:0.6:0.9
No. 4 to 1 in...	½ to 1	1:1.2:3.1	1:1.3:3.1	1:1.5:3.0	1:1.8:2.9	1:2.1:2.7
	3 to 4	1:0.9:2.7	1:1.1:2.6	1:1.2:2.6	1:1.4:2.5	1:1.7:2.3
	6 to 7	**1:0.6:2.0**	**1:0.7:2.0**	**1:0.8:2.0**	**1:0.9:1.9**	**1:1.1:1.8**
	8 to 10	1:0.3:1.2	1:0.3:1.2	1:0.4:1.2	1:0.5:1.2	1:0.6:1.2
No. 4 to 1½ in.	½ to 1	1:1.1:3.6	1:1.2:3.5	1:1.5:3.5	1:1.7:3.4	1:2.0:3.2
	3 to 4	1:0.9:3.0	1:1.0:2.9	1:1.2:2.9	1:1.4:2.9	1:1.6:2.7
	6 to 7	**1:0.6:2.2**	**1:0.7:2.2**	**1:0.8:2.2**	**1:0.9:2.2**	**1:1.1:2.1**
	8 to 10	1:0.3:1.4	1:0.3:1.3	1:0.4:1.4	1:0.5:1.4	1:0.5:1.3
No. 4 to 2 in...	½ to 1	1:1.0:4.1	1:1.1:4.1	1:1.2:4.1	1:1.4:4.1	1:1.6:4.0
	3 to 4	1:0.8:3.4	1:0.9:3.4	1:1.0:3.5	1:1.1:3.4	1:1.3:3.4
	6 to 7	**1:0.5:2.6**	**1:0.6:2.6**	**1:0.6:2.7**	**1:0.7:2.6**	**1:0.9:2.6**
	8 to 10	1:0.2:1.6	1:0.3:1.6	1:0.3:1.7	1:0.4:1.7	1:0.4:1.7
⅜ to 1 in......	½ to 1	1:1.4:3.1	1:1.5:3.0	1:1.8:2.9	1:2.1:2.8	1:2.4:2.6
	3 to 4	1:1.1:2.6	1:1.3:2.6	1:1.5:2.5	1:1.7:2.4	1:2.0:2.2
	6 to 7	**1:0.8:2.0**	**1:0.8:2.0**	**1:1.2:1.9**	**1:1.1:1.9**	**1:1.3:1.8**
	8 to 10	1:0.4:1.2	1:0.4:1.2	1:0.5:1.2	1:0.6:1.2	1:0.7:1.1
⅜ to 1½ in....	½ to 1	1:1.4:3.5	1:1.5:3.4	1:1.7:3.4	1:2.0:3.3	1:2.3:3.1
	3 to 4	1:1.1:3.0	1:1.2:2.9	1:1.4:2.9	1:1.6:2.8	1:1.9:2.6
	6 to 7	**1:0.6:2.2**	**1:0.8:2.2**	**1:1.0:2.2**	**1:1.1:2.1**	**1:1.3:2.0**
	8 to 10	1:0.4:1.4	1:0.4:1.4	1:0.5:1.4	1:0.6:1.3	1:0.7:1.3
⅜ to 2 in......	½ to 1	1:1.3:4.0	1:1.4:4.0	1:1.6:4.0	1:1.9:3.9	1:2.1:3.8
	3 to 4	1:1.0:3.4	1:1.2:3.4	1:1.3:3.3	1:1.5:3.3	1:1.7:3.2
	6 to 7	**1:0.7:2.6**	**1:0.8:2.5**	**1:0.9:2.6**	**1:1.0:2.6**	**1:1.1:2.5**
	8 to 10	1:0.4:1.6	1:0.4:1.6	1:0.5:1.6	1:0.5:1.6	1:0.6:1.6
¾ to 1½ in....	½ to 1	1:1.6:3.2	1:1.8:3.2	1:2.1:3.2	1:2.4:3.1	1:2.7:2.9
	3 to 4	1:1.3:2.7	1:1.5:2.7	1:1.7:2.7	1:2.0:2.6	1:2.3:2.5
	6 to 7	**1:0.9:2.0**	**1:1.0:2.1**	**1:1.2:2.0**	**1:1.4:2.0**	**1:1.5:1.8**
	8 to 10	1:0.5:1.2	1:0.5:1.3	1:0.6:1.3	1:0.7:1.3	1:0.8:1.2
¾ to 2 in......	½ to 1	1:1.6:3.7	1:1.8:3.7	1:2.0:3.7	1:2.4:3.6	1:2.6:3.5
	3 to 4	1:1.3:3.1	1:1.5:3.1	1:1.6:3.1	1:1.9:3.1	1:2.2:3.0
	6 to 7	**1:0.9:2.4**	**1:1.1:2.4**	**1:1.1:2.4**	**1:1.3:2.4**	**1:1.5:2.3**
	8 to 10	1:0.5:1.5	1:0.5:1.5	1:0.6:1.5	1:0.7:1.5	1:0.8:1.5
¾ to 3 in......	½ to 1	1:1.6:4.2	1:1.8:4.2	1:2.0:4.2	1:2.3:4.1	1:2.6:4.0
	3 to 4	1:1.3:3.5	1:1.5:3.6	1:1.6:3.6	1:1.9:3.6	1:2.1:3.5
	6 to 7	**1:0.9:2.6**	**1:1.0:2.6**	**1:1.1:2.6**	**1:1.3:2.6**	**1:1.4:2.6**
	8 to 10	1:0.5:1.6	1:0.5:1.6	1:0.6:1.7	1:0.7:1.7	1:0.8:1.7

APPENDIX 7

TENTATIVE METHOD OF TEST

FOR

CONSISTENCY OF PORTLAND CEMENT CONCRETE

American Society for Testing Materials

Serial Designation: D 138–25 T

This is a **Tentative Standard** only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the Society and until its adoption as Standard it is subject to revision.

ISSUED, 1922; REVISED 1925

1. Scope. This test covers the method to be used both in the laboratory and in the field for determining consistency of concrete.[1]

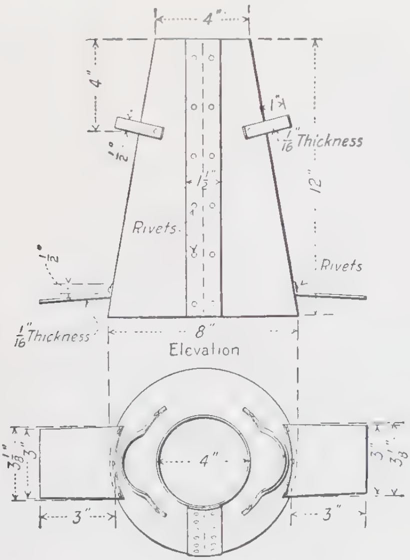


FIG. 1.

[1] This test is not considered applicable when there is a considerable amount of coarse aggregate over 2 in. in size in the concrete. The committee is now working on a method suitable for determining the consistency of concrete using aggregate over 2 in. in size.

2. Apparatus. The test specimen shall be formed in a mold of No. 16 gage galvanized metal in the form of the lateral surface of the frustrum of a cone with the base 8 in. in diameter, the upper surface 4 in. in diameter, and the altitude 12 in. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mold shall be provided with foot pieces and handles as shown in Fig. 1.

3. Sample. When the test is made at the mixer, the sample shall be taken from the pile of concrete immediately after the entire batch has been discharged. When testing concrete that has been hauled from a central mixing plant, the sample shall be taken from the concrete immediately after it has been dumped on the subgrade.

4. Procedure. The mold shall be placed on a flat, non-absorbent surface, such as a smooth plank or a slab of concrete, and the operator shall hold the form firmly in place, while it is being filled, by standing on the foot pieces. The mold shall be filled to about one-fourth of its height with the concrete which shall then be puddled, using 20 to 30 strokes of a $\frac{1}{2}$-in. rod pointed at the lower end. The filling shall be completed in successive layers similar to the first and the top struck off so that the mold is exactly filled. The mold shall then be removed by being raised vertically, immediately after being filled. The molded concrete shall then be allowed to subside, until quiescent, and the height of the specimen measured.

5. Slump. The consistency shall be recorded in terms of inches of subsidence of the specimen during the test, which shall be known as the slump.

$$\text{Slump} = 12 - \text{inches of height after subsidence}$$

APPENDIX 8

STANDARD METHODS

OF

MAKING COMPRESSION TESTS OF CONCRETE

American Society for Testing Materials

Serial Designation: C 39–25

These methods are issued under the fixed designation C 39; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

Proposed as Tentative, 1921; Adopted, 1925

1. Scope. These methods are intended to cover compression tests of concrete made in a laboratory where accurate control of quantities of materials and test conditions is possible. They are designed to apply primarily to hand-mixed concrete. These methods may be used with slight modification in making tests of concrete for wearing resistance, bond between con-

crete and steel, impermeability, etc. The investigation of machine-mixed concrete will require certain obvious changes in the method. For methods of conducting compression tests of concrete specimens made during the progress of construction work, see the Standard Methods of Making and Storing Specimens of Concrete in the Field (Serial Designation: C 31) of the American Society for Testing Materials.[1]

2. Preparation of Materials. Materials shall be brought to room temperatures (65 to 75°F.) before beginning tests. Cement shall be stored in a dry place; preferably in covered metal cans. The cement shall be thoroughly mixed in advance, in order that the sample may be uniform throughout the tests. It shall be sifted through a No. 16 sieve and all lumps rejected. Aggregates shall be in a room-dry condition when used in concrete tests. In general, aggregates should be separated on the No. 4, $\frac{3}{8}$-in. and $1\frac{1}{2}$-in. sieves[2] and recombined to the average original sieve analysis for each batch. Fine aggregate should be separated into different sizes also, in cases where unusual gradings are being studied.

3. Sampling for Preliminary Tests. Representative samples[3] of all concrete materials shall be secured for preliminary tests prior to the proportioning and mixing of the concrete. Cement test samples may be made up of a small quantity from each sack used in the concrete tests. Test samples of aggregates may be taken from larger lots by quartering.

4. Cement Tests. Cement shall be subjected to test, using the methods described in the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9) of the American Society for Testing Material.[4]

5. Fine Aggregate Tests. Fine aggregates (passing through a No. 4 sieve) shall be subjected, when required, to the following tests:

(*a*) Sieve analysis test made in accordance with the Standard Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C 41) of the American Society for Testing Materials.[5]

(*b*) Test for organic impurities (natural sand only) made in accordance with the Standard Method of Test for Organic Impurities in Sands for Concrete (Serial Designation: C 40) of the American Society for Testing Materials.[6]

[1] 1924 Book of American Society for Testing Materials Standards and Appendix 9.

[2] For specifications for sieves, see Standard Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C 41) of the American Society for Testing Materials, Appendix 3.

[3] For methods of sampling large lots of deposits of aggregate, see the Standard Methods of Sampling Stone, Slag, Gravel, Sand, etc., for Use as Highway Materials (Serial Designation: D 75) of the American Society for Testing Materials, 1924 Book of A. S. T. M. Standards.

[4] Appendix 1.

[5] Appendix 3.

[6] Appendix 5.

(*c*) Test for quantity of silt, clay, or dust made in accordance with the Tentative Method of Decantation Test for Sand and Other Fine Aggregates (Serial Designation: D 136–22 T) of the American Society for Testing Materials.[1]

(*d*) Test for unit weight made in accordance with the Standard Method of Test for Unit Weight of Aggregate for Concrete (Serial Designation: C 29) of the American Society for Testing Materials.[2]

(*e*) Strength test of 1:3 mortar by weight at 7 and 28 days in comparison with standard sand mortar.

6. Coarse Aggregate Tests. Coarse aggregates (retained on a No. 4 sieve) shall be subjected when required to the following tests:

(*a*) Sieve analysis test as specified under Sec. 5 (*a*);

(*b*) Test for quantity of silt, clay, or dust, as specified under Sec. 5 (*c*);

(*c*) Test for unit weight as specified under Sec. 5 (*d*).

7. Mixed Aggregate Tests. The unit weight of mixed fine and coarse aggregates as used in concrete tests shall be determined in accordance with the method specified in Sec. 5 (*d*).

8. Proportioning. The quantities of each size of aggregate to be used in each batch shall be determined on the basis of the sieve analysis and the unit weight of the mixed aggregate. The exact quantities of cement and of each size of aggregate for each batch shall be determined by weight. The quantity of water for each batch shall be accurately measured. The quantities of materials may be expressed as (*a*) 1 volume of cement to — volumes of total aggregate mixed as used, or (*b*) 1 volume of cement — volumes fine aggregate, and — volumes of coarse aggregate.

NOTE.—It is impracticable to give a general method for proportioning concrete for experimental purposes; the details will necessarily vary widely with the purpose for which the tests are made. The following procedure is suggested for specific cases:

(*a*) Vary the cement content by 10 per cent intervals above and below assumed quantity.

(*b*) Vary the proportions of fine to coarse aggregate, measured separately, at intervals of 10 per cent.

(*c*) Vary the quantity of mixing water by intervals of 10 per cent.

9. Size of Test Pieces. Compression tests of concrete shall be made on cylinders of a diameter equal to one-half the length. The standard shall be 6- × 12-in. cylinders where the coarse aggregate does not exceed 2 in. in size; for aggregates larger than 2 in., 8- × 16-in. cylinders shall be used; 2- × 4-in. cylinders may be used for mixtures without coarse aggregate.

10. Mixing Concrete. (*a*) Concrete shall be mixed by hand in batches of such size as to leave a small quantity of concrete after molding a single test piece. The batch shall preferably be mixed in a shallow galvanized steel pan with a 10-in. bricklayer's trowel which has been blunted by cutting off about 2½ in. of the point, as follows:

[1] Appendix 4.

[2] Appendix 2.

(*b*) The cement and fine aggregate shall be mixed dry until the mixture is homogeneous in color;

(*c*) The coarse aggregate shall be added and mixed dry;

(*d*) Sufficient water shall be added to produce concrete of the required workability;

NOTE.—Concrete tests should be made on *plastic* mixtures. It is of the utmost importance that a uniform degree of workability be secured in tests involving comparisons of different materials and methods.

(*e*) The whole shall be mixed thoroughly until the entire mass is homogeneous in appearance.

11. Workability. The workability or plasticity of each batch of concrete shall be measured immediately after mixing by one of the following methods:

(*a*) Slump test made in accordance with the Tentative Method of Test for Consistency of Portland Cement Concrete (Serial Designation: D 138 - 25 T) of the American Society for Testing Materials.[1]

(*b*) Flow test made by placing a metal form in the shape of a frustum of a cone $6\frac{3}{4}$ in. in top diameter, 10 in. in bottom diameter, 5 in. deep, on the table of the flow apparatus.[2] The fresh concrete shall be placed in the mold in two layers. Each layer shall be puddled and finished as described in Sec. 13. Immediately after molding, the form shall be removed by a steady upward pull; the specimen raised $\frac{1}{2}$ in. and dropped fifteen times in about 6 sec. by means of a suitable cam and crank. The spread of the fresh concrete due to this treatment, as compared with the original bottom diameter of the cone, expressed as a percentage, is the "flow."

12. Forms. The forms shall preferably be of metal. Each form shall be provided with a machined metal base plate, and shall be oiled with a heavy mineral oil before using. Particular care shall be taken to obtain tight forms so that the mixing water will not escape during molding.

NOTE.—The best type of form consists of lengths of cold-drawn steel tubing, split along one element and closed by means of a circumferential band and bolt. Satisfactory forms can be made from lengths of steel water-pipe machined on the inside, from rolled metal plates, from galvanized steel, machined iron or steel castings. Paraffined cardboard molds will give good results under expert supervision.

13. Molding Test Pieces. Concrete test pieces shall be molded by placing the fresh concrete in the form in layers 3 to 4 in. in thickness. Each layer shall be puddled with twenty-five strokes with a $\frac{5}{8}$-in. round steel bar of a length 9 in. greater than the length of the mold, pointed at the lower end. After the top layer has been puddled, the surplus concrete shall be cleaned off with a trowel, and the mold covered with a machined metal plate or a piece of plate glass at least $\frac{1}{4}$ in. thick, which will be used later in capping the test piece.

[1] Appendix 7.

[2] For a description and illustration of one design for a flow table, see *Proceedings*, American Society for Testing Materials, Vol. XX, Part II, p. 242 (1920); and *Concrete*, p. 274, June, 1920.

14. Capping Cylinders. Two to four hours after molding, the test pieces shall be capped with a thin layer of stiff, neat cement paste, in order that the cylinders may present a smooth end for loading. The cap shall be formed by means of a machined metal plate or a piece of plate glass of suitable size, at least $\frac{1}{4}$ in. thick, worked down on the fresh cement paste until it rests on the top of the cylinder form. The cement for capping shall be mixed to a stiff paste before beginning to mix the concrete; in this way the tendency of the cap to shrink will be largely eliminated. The adhesion of the concrete to the metal base plate and the glass can be largely eliminated by oiling the cover plate and by inserting a sheet of paraffined tissue paper.

15. Curing Test Pieces. Concrete test pieces shall be removed from the forms 20 to 48 hr. after molding, marked, weighed, and stored in damp sand, under damp cloths or in a moist chamber until the date of test. The temperature of the curing room should not fall outside the range of 60 to 75°F.

16. Age at Test. Tests shall be made at the age of 7 and 28 days; ages of 3 months and 1 year are recommended, if longer-time tests are required.

17. Sequence of Tests. Three to five test pieces should be made on different days in investigations in which accurate comparisons are desired.

18. Preparation of Tests. Compression tests shall be made immediately upon removal of the concrete test pieces from the curing room; that is, the test pieces shall be loaded in a damp condition. The length and average diameter of the test piece shall be measured in inches and hundredths; two diameters shall be measured at right angles near the mid-length. The test piece shall be weighed immediately before testing.

19. Method of Testing. In general, only the ultimate compressive strength of the cylinders need be observed. The metal bearing plates of the testing machine shall be placed in contact with the ends of the test piece; cushioning materials shall not be used. An adjustable bearing block shall be used to transmit the load to the test piece. The bearing block shall be placed on *top* of the test piece in vertical testing machines. The diameter of the bearing block shall be approximately the same as that of the test piece. The upper section of the bearing block shall be kept in motion as the head of the testing machine is brought to a bearing on the test piece.

20. Application of Load. The load shall be applied uniformly and without shock. The moving head of the testing machine should travel at the rate of about 0.05 in. per min. when the machine is running idle.

21. Record of Tests. The total load indicated by the testing machine at failure of the test piece shall be recorded and the unit compressive strength calculated in pounds per square inch, the area computed from the average diameter of the cylinder being used. The type of failure and appearance of the concrete shall be noted.

22. Weight of Concrete. The weight of the concrete in pounds per cubic foot shall be determined from the weight of the specimens and their dimensions.

23. Density and Yield. Density and yield of concrete when required shall be calculated from the unit volumes of the constituent materials and the volume of the concrete. Density is here understood to be the ratio of solids in the concrete to the total volume of the mass. Yield is the volume of concrete resulting from one volume of aggregate mixed as used.

24. Report of Tests. The report of tests shall include the following:

(*a*) The kind and origin of concrete materials.

(*b*) Complete data on all tests of cement and aggregates.

(*c*) A description of methods of making and testing the concrete, where methods deviate from the proposed standards.

(*d*) The quantities of cement, aggregates, and water in each batch.

(*e*) The method of measuring workability or plasticity with "slump" or "flow" of concrete.

(*f*) The quantity of water expressed as a ratio to volume of cement.

(*g*) The age at test.

(*h*) The size of test pieces.

(*i*) The date of molding and testing each cylinder.

(*j*) The compressive strength in pounds per square inch of each test piece and average of tests in a set.

(*k*) A description of failure and appearance of concrete on each test piece.

(*l*) The unit weight, density, and yield of the concrete.

APPENDIX 9

STANDARD METHODS

OF

MAKING AND STORING SPECIMENS OF CONCRETE IN THE FIELD

American Society for Testing Materials

Serial Designation: C 31–21

These methods are issued under the fixed designation C 31; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1902; ADOPTED, 1921

1. Scope. The methods herein specified apply to molding and storing of test specimens of concrete sampled from concrete being used in construction.

2. Size and Shape of Specimen. The test specimens shall be cylindrical in form with the length twice the diameter. In general, a mold whose diameter is not less than four times the diameter of the largest size aggregate shall be used. (The sizes most commonly used are 6- × 12-in. and 8- × 16-in. cylinders.)

3. Molds. (*a*) The molds shall be cylindrical in form, made of non-absorbent material, and shall be substantial enough to hold their form during the molding of the test specimens. They shall not vary in diameter more than 1/16 in. in any direction, nor shall they vary in height more than 1/16 in. from the height required. They shall be substantially watertight, so that there will be no leakage of water from the test specimen during molding.

(*b*) Each mold shall be provided with a base plate having a plane surface and made of non-absorbent material. This plate shall be large enough in

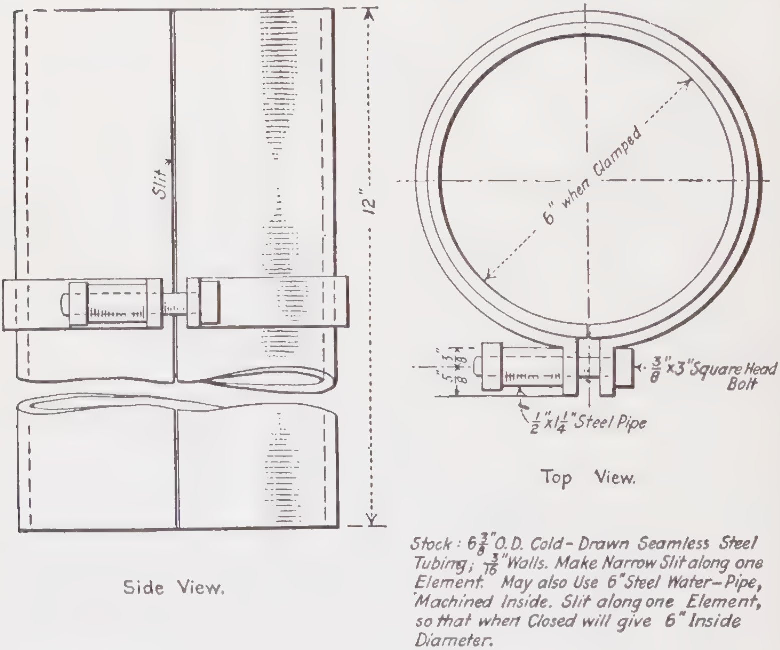


Fig. 1.

diameter properly to support the form without leakage. Plate glass or planed metal is satisfactory for this purpose. A similar plate should be provided for covering the top surface of the test specimen after being molded.

(*c*) Suggestions for suitable forms are shown in Figs. 1, 2, and 3.

4. Sampling of Concrete. (*a*) Concrete for the test specimens shall be taken immediately after it has been placed in the work. All the concrete for each sample shall be taken from one place. A sufficient number of samples—each large enough to make one test specimen—shall be taken at different points so that the test specimens made from them will give a fair average of the concrete placed in that portion of the structure selected for

tests. The location from which each sample is taken shall be noted clearly for future reference.

(*b*) In securing samples, the concrete shall be taken from the mass by a shovel or similar implement and placed in a large pail or other receptacle, for transporting to the point of molding. Care shall be taken to see that each test specimen represents the total mixture of the concrete at that place. Different samples shall not be mixed together, but each sample shall make one specimen.

5. Molding the Specimens. (*a*) The pails or other receptacles containing the samples of concrete shall be taken as quickly as possible to the place

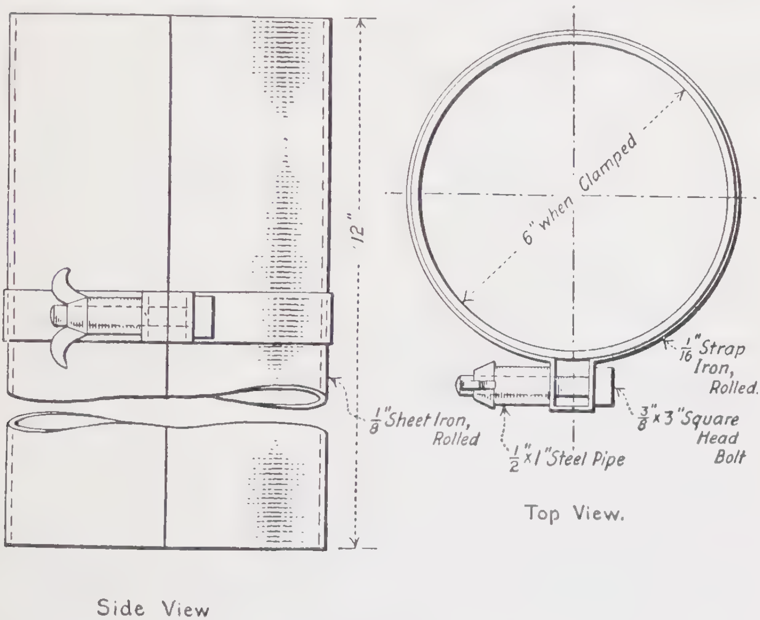


Fig. 2.

selected for molding test specimens. To offset segregation of the concrete occurring during transportation, each sample shall be dumped into a non-absorbent water-tight receptacle and, after slight stirring, immediately placed in the mold.

(*b*) The test specimens shall be molded by placing the concrete in the form in layers approximately 4 in. in thickness. Each layer shall be puddled with twenty-five to thirty strokes with a 5/8- to 3/4-in. bar about 2 ft. long, tapered slightly at the lower end. After puddling the top layer, the surface concrete shall be struck off with a trowel and covered with the top plate, which will later be used in capping the test specimens.

6. Capping Specimens. Two to four hours after molding, the test specimens shall be capped with a thin layer of stiff, neat cement paste, in order

that the cylinder may present a smooth end for testing. The cap can best be formed by means of a piece of plate glass 1/4 in. thick, and of a diameter 2 or 3 in. larger than that of the mold. This plate is worked on the fresh cement paste until it rests on top of the form. The cement for capping should be mixed to a stiff paste some time before it is to be used in order to avoid the tendency of the cap to shrink. Adhesion of the concrete to the top and bottom plates can be avoided by oiling the plates or by inserting a sheet of paraffined tissue paper.

7. Removal of Specimens from Forms. At the end of 48 hr., the test specimens shall be removed from the molds and buried in damp sand, except

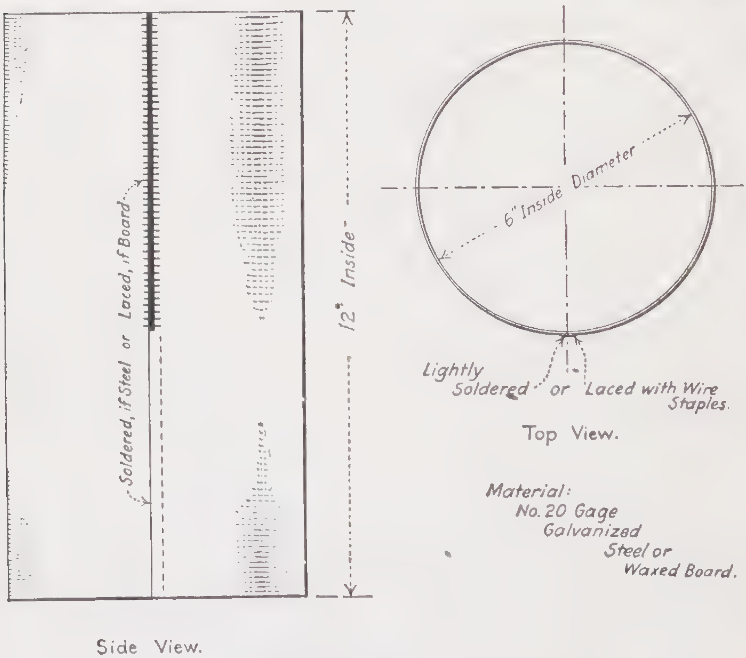


FIG. 3.

in case the molds shown in Fig. 3 are used; in this case test specimens may be buried in damp sand without removal of the mold, thus permitting shipping of the test specimens in the molds.

8. Storage of Specimens. (*a*) The test specimens shall remain buried in damp sand until 10 days prior to the date of test. They shall then be well packed in damp sand or wet shavings and shipped to the testing laboratory, where they shall be stored either in a moist room or in damp sand until the date of test.

(*b*) Should a 7-day test be required, the test specimens shall remain at the works as long as possible to harden, and then shall be shipped so as to arrive at the laboratory in time to make the test on the required date.

APPENDIX 10

From the 1924 *Report* of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete.

EFFECT OF OILS AND MISCELLANEOUS LIQUIDS ON CONCRETE AND METHOD OF PROTECTIVE TREATMENT WHERE REQUIRED

Liquid	Effect on untreated concrete	Surface treatment
	MINERAL OILS[1]	
30° Baumé or heavier. .	Good concrete unaffected. Very slight surface penetration.	None—Good concrete well spaded, or cement mortar finish sufficient.
Fuel oils above 30° Baumé Distillates Gas and lubricating oils[2]	Good concrete unaffected. More penetration than for heavy oils.	Coatings of the magnesium fluosilicate class, glues, or varnishes required for storage tanks.
Kerosene, gasoline, benzine.	Good concrete unaffected. Considerable penetration.	Gasoline-proof coatings producing glazed surface or treatment with iron compounds.
	ANIMAL OILS (SOLID FATS)[3]	
Lard and lard oil.	May attack concrete slowly, particularly if in melted condition.	Various proprietary compounds recommended by manufacturers of technical paints.
Goose fat, beef marrow, beef and mutton tallow and tallow oil.	No definite information. Probably similar to lard oil.	Probably similar to that for lard oil.

[1] Signal oil, used by railroads, is a mixture of animal fat with mineral oil. Probably has about the same effect on concrete as lard oils.

[2] Some lubricating oils are mixtures of mineral and animal oils.

[3] Bureau of Standards tests with concrete tanks show slight roughening of surface at end of 12 months, and considerable deposit on surface through saponification.

Liquid	Effect on untreated concrete	Surface treatment
Animal Oils (Liquid Fats)		
Marine:		
Menhaden oil	No effect on good concrete.	Cushman's tests indicate various coatings no better than plain concrete.
Cod liver oil Shark liver oil Seal and whale oil	More or less disintegration depending on quality of concrete.	Various proprietary compounds recommended by manufacturers of technical paints.
Terrestrial:		
Sheep's foot Horse's foot	More or less disintegration depending on quality of concrete.	Various proprietary compounds recommended by manufacturers of technical paints.
Neat's foot[1]	No effect on good concrete.	No treatment required.
Vegetable Oils (Solid Fats)		
Cocoanut oil[2]	Some action if stored in closed tank. Progressive disintegration if in contact with surfaces exposed to air.	Several proprietary compounds seem to have proved effective on floors. Sodium silicate or magnesium fluosilicate treatment apparently sufficient for closed tanks.
Palm oil	No information.	No information.
Vegetable Oils		
Drying: Hemp oil Poppyseed oil Tobacco oil	No information.	No information.

[1] Bureau of Standards noted slight deposit due to saponification at end of 12 months.

[2] Bureau of Standards tests with concrete tanks show considerable softening and roughening of surface at end of 12 months.

Liquid	Effect on untreated concrete	Surface treatment
	VEGETABLE OILS (*Continued*)	
Linseed oil[1] Rosin oil.......... Turpentine........	No effect on good concrete. Considerable penetration of turpentine.	Cushman's tests indicate various coatings no better than plain concrete for linseed and rosin oils.
Semidrying:		
Cottonseed oil.......	No action if stored in closed tank of good concrete.	Same as for cocoanut oil.
Rape seed oil...... Castor oil......... Mustard oil.......	Progressive disintegration, if in contact with surfaces exposed to air.	
Non-drying:		
Olive oil....	Probably some action.	Cushman's tests show proprietary coatings of varnish type effective.
Butter oil (?)		
	MISCELLANEOUS LIQUIDS	
Tanning liquors........	Acid liquors show considerable effect. Other tanning extracts have no action.	Bituminous acid-proof paints effective for tanks holding acid tanning solutions. Good concrete with or without mortar finish sufficient for other tanning liquors.
Sulfite liquor.	Attacks untreated concrete tanks.	Cushman's tests indicate bituminous acid-proof paints effective. Paraffin coating fair.
Cider vinegar..........	Acetic acid attacks concrete.	Cushman's tests indicate bituminous acid-proof paints effective. Paraffin coatings applied hot also useful for tanks.

[1] Bureau of Standards noted at end of 12 months considerable deposit on surfaces of concrete tanks containing both boiled and raw linseed oil, due to saponification, but concrete showed no deterioration.

Liquid	Effect on untreated concrete	Surface treatment
MISCELLANEOUS LIQUIDS (*Continued*)		
Sauerkraut brine	No action on good concrete.	Cushman's tests show special treatments no better than untreated concrete.
Whey	More or less action depending on quality of concrete.	Cushman's tests show proprietary coating of varnish type effective. Sodium silicate treatment used on storage tanks.
Buttermilk	No action on good concrete.	Untreated tanks used successfully to store buttermilk.
Molasses	No action in closed concrete.	Good concrete well spaded or finished with cement mortar sufficient. Annapolis mixture sometimes used.
Sulfuric acid solutions	Progressive disintegration, particularly where concrete is subject to abrasion.	Bituminous acid-proof paints or mastic coating effective.

APPENDIX 11

STANDARD SPECIFICATIONS FOR CONCRETE BUILDING BLOCK AND CONCRETE BUILDING TILE

American Concrete Institute

Submitted by Committee P-1, on Standard Building Units

Serial Designation P–1A–25

1. GENERAL

1. The purpose of these specifications is to define the requirements for concrete building block and concrete building tile to be used in construction.

2. The word "concrete" shall be understood to mean portland cement concrete.

3. Strength Requirements. According to the strength in compression 28 days after being manufactured or when shipped, concrete block and concrete tile shall be classified as heavy-load-bearing, load bearing, and non-load-bearing on the basis of the following requirements:

Name of classification	Compressive strength, pounds per square inch of gross cross-sectional area as laid in the wall	
	Average of 3 or more units	Minimum for individual unit
Heavy-load-bearing block or tile..........	1200	1000
Medium-load-bearing block or tile........	700	600
Non-load-bearing block or tile............	250	200

4. The gross cross-sectional area of a one-piece concrete block or tile shall be considered as the product of the length times the width of the unit as laid in the wall. No allowance shall be made for air spaces in hollow units. The gross cross-sectional area of each unit of a two-piece block or tile shall be considered the product of the length of the unit times one-half the thickness of the wall for which the two-piece block or tile is intended.

5. The compressive strength of the concrete in units of all classifications except "non-load-bearing block" shall be at least 1000 lb. per sq. in., when calculated on the minimum cross-sectional area in bearing.

6. Absorption Requirements. Concrete building block and tile to be exposed to soil or weather in the finished work (without stucco, plaster, or other suitable protective covering) shall meet the requirements of the absorption test.

7. All concrete building block and tile not covered by Paragraph 6 need not meet an absorption requirement.

8. Concrete block and tile shall not absorb more than 10 per cent of the dry weight of the unit, when tested as hereinafter specified, except when it is made of concrete weighing less than 140 lb. per cu. ft. For block or tile made with concrete weighing less than 140 lb. per cu. ft., the absorption in per cent by weight shall not be more than 10 multiplied by 140 and divided by the unit weight in pounds per cubic foot of the concrete under consideration.

9. Sampling.—Specimens for tests shall be representative of the commercial product of the plant.

10. Not less than three and preferably five specimens shall be required for each test.

11. The specimens used in the absorption test may be used for the strength test.

2. METHODS OF TESTING

12. Absorption Test.—The specimens shall be immersed in clean water at approximately 70°F. for a period of 24 hr. They shall then be removed, the surface water wiped off, and the specimens weighed. Specimens shall

be dried to a constant weight at a temperature of from 212 to 250°F. and reweighed. Absorption is the difference in weight divided by the weight of the dry specimens and multiplied by 100.

13. Weight of Concrete.—The weight per cubic foot of the concrete in a block or tile is the weight of the unit in pounds divided by its volume in cubic feet. To obtain the volume of the unit, fill a vessel with enough water to immerse the specimen. The greatest accuracy will be obtained with the smallest vessel in which the specimen can be immersed with its length vertical. Mark the level of the water, then immerse the saturated specimen and weigh the vessel. Draw the water down to its original level, and weigh the vessel again. The difference between the two weights divided by 62.5 equals the volume of the specimen in cubic feet.

14. Strength Test.—Specimens for the strength test shall be dried to constant weight at a temperature of from 212 to 250°F.

15. The specimens to be tested shall be carefully measured for overall dimensions of length, width, and height.

16. Bearing surfaces shall be made plane by capping with plaster of paris or a mixture of portland cement and plaster, which shall be allowed to harden thoroughly before the test.

17. Specimens shall be accurately centered in the testing machine.

18. The load shall be applied through a spherical bearing block placed on top of the specimen.

19. When testing other than rectangular block or tile, care must be taken to see that the load is applied through the center of gravity of the specimen.

20. Metal plates of sufficient thickness to prevent appreciable bending shall be placed between the spherical bearing block and the specimen.

21. The specimen shall be loaded to failure.

22. The compressive strength in pounds per square inch of gross cross-sectional area is the total applied load in pounds divided by the gross cross-sectional area in square inches.

APPENDIX 12

STANDARD SPECIFICATION FOR CONCRETE BRICK

Submitted by Committee P-1, on Standard Building Units

American Concrete Institute

(Serial Designation P-1B-25)

1. GENERAL

1. The purpose of these specifications is to define the requirements for concrete brick to be used in construction.

2. The word "concrete" shall be understood to mean portland cement concrete.

3. The average compressive strength of concrete brick 28 days after being manufactured or when shipped shall not be less than 1500 lb. per sq. in. of gross cross-sectional area as laid in the wall, and the compressive strength of any individual brick shall be not less than 1000 lb. per sq. in. of gross cross-sectional area as laid in the wall.

4. The gross cross-sectional area of a brick shall be considered as the product of the length times the width of the unit as laid in the wall.

5. Concrete brick shall not absorb more than 12 per cent of the dry weight of the brick when tested as hereinafter specified, except when they are made of concrete weighing less than 125 lb. per cu. ft. For brick made of concrete weighing less than 125 lb. per cu. ft., the average absorption in per cent by weight shall not be more than 12 multiplied by 125 and divided by the unit weight in pounds per cubic foot of the concrete under consideration.

6. Specimens for tests shall be representative of the commercial product of the plant.

7. Five specimens shall be required for each test.

8. The specimens used in the absorption test may be used for the strength test.

2. METHODS OF TESTING

9. **Absorption Test.** The specimens shall be immersed in clean water at approximately 70°F. for a period of 24 hr. They shall then be removed, the surface water wiped off, and the specimens weighed. Specimens shall be dried to a constant weight at a temperature of from 212 to 250°F., and reweighed. Absorption is the difference in weight divided by the weight of the dry specimens and multiplied by 100.

10. **Strength Test.**—Specimens for the strength test shall be dried to constant weight at a temperature of from 212 to 250°F.

11. The specimens to be tested shall be carefully measured for overall dimensions of length, width, and thickness.

12. Bearing surfaces shall be made plane by capping with plaster of Paris or a mixture of portland cement and plaster, which shall be allowed to harden thoroughly before the test.

13. Specimens shall be accurately centered in the testing machine.

14. The load shall be applied through a spherical bearing block placed on top of the specimen.

15. Metal plates of sufficient thickness to prevent appreciable bending shall be placed between the spherical bearing block and the specimen.

16. The specimen shall be loaded to failure.

17. The compressive strength in pounds per square inch of gross cross-sectional area is the total applied load in pounds divided by gross cross-sectional area in square inches.

APPENDIX 13

SPECIFICATIONS FOR PORTLAND CEMENT CONCRETE PAVEMENTS

American Concrete Institute

ONE-COURSE PORTLAND CEMENT CONCRETE PAVEMENTS FOR HIGHWAYS

I. GENERAL

1. It is the intent of these specifications to cover the requirements for the materials and construction of Portland Cement Concrete Highway Pavement wherein the concrete is of uniform proportions from top to bottom of slab.

II. MATERIALS

(A) Cement

2. Cement shall be a standard portland cement which, at the time it is incorporated in the pavement mixture, shall conform to the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9–21) of the American Society for Testing Materials, and subsequent revisions thereof.

(B) Aggregates

3. Prior to placing any orders for aggregates, the contractor shall advise the engineer of the proposed source or sources of supply of aggregates. The engineer may require the contractor to submit 50-lb. samples of all aggregates proposed for use. If the engineer finds such samples fulfill the requirements of these specifications for aggregates, similar material shall be considered as acceptable. Acceptance of samples shall not be construed as a guarantee of acceptance of all materials from the same source, and it shall be understood that any aggregates which do not meet with the requirements of these specifications will be rejected. Upon receiving notification of the proposed source or sources of aggregate supply, the engineer may elect to investigate and test the aggregate supply at the source; in which case he shall notify the contractor as to acceptability, or non-acceptability of the proposed aggregates. The engineer shall notify the contractor, after agreement upon a source or sources of aggregate supply, whether routine tests of aggregates during construction will be made at the source of supply or at the point of receipt.

4. (*a*) *Fine Aggregate.*—Fine aggregate shall consist of natural sand, stone screenings, slag sand, tailings, chatts, or other inert materials with

similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains. When incorporated in the pavement mixture, fine aggregate shall be free from frost, frozen lumps, injurious amounts of dust, mica, soft or flaky particles, shale, alkali, organic matter, loam, or other deleterious substances. Ninety-five per cent of the fine aggregate, when dry, shall pass a one-fourth (¼)-inch sieve; not more than 25 per cent shall pass a 50-mesh sieve, and not more than 5 per cent by weight shall pass a 100-mesh sieve. In no case shall fine aggregate be accepted containing more than 3 per cent, by dry weight, nor more than 5 per cent by dry volume, nor more than 7 per cent by wet volume, of clay, loam, or silt. If any sample of fine aggregate shows more than 7 per cent of clay, loam, or silt, in 1 hr.'s settlement after shaking in an excess of water, the material represented by the sample will be rejected. Fine aggregate shall be of such a quality that mortar composed of portland cement and the fine aggregate, when made into 2- × 4-in. cylinders, in the same proportions as will be used in the concrete mixture for the pavement, shall show compressive strength at 7 and 28 days equal to, or greater than, the compressive strength of cylinders composed of mortar of the same proportions of portland cement and standard Ottawa sand. For proportioning test cylinders, portland cement and fine aggregate and standard Ottawa sand shall be measured by weight and the same portland cement shall be used with the Ottawa sand as with the fine aggregate to be tested.

5. (*b*) *Coarse Aggregate.*—Coarse aggregate shall consist of one of the following materials, or a combination thereof; crushed rock, pebbles (gravel), air-cooled blast-furnace slag, chatts, or tailings. The particles of coarse aggregate shall be of clean, hard, tough, durable material, free from vegetable or other deleterious substances, and shall contain no soft, flat, or elongated pieces. Coarse aggregate, except air-cooled blast-furnace slag, shall show not more than 6 per cent loss in the wear test.

(Note: In many cases, it will be necessary for the engineer to specify the sizes, grading, and quality of coarse aggregate in accordance with local conditions. In every case, the engineer should provide specifications which will require the use of the best coarse aggregate which is economically available. The following specifications covering size and grading of coarse aggregate will be found applicable in most sections of the country, and are intended for use with the 1:2:3½, 1:2:3, or 1:1½:3, mixture.)

6. The size of the coarse aggregate shall be such as to pass a 3-in. round opening. Coarse aggregate shall be uniformly graded within the limits shown in the following table, and any material which does not come within the limits specified shall be rejected.

Passing 3-in. round opening, 100 per cent.

Passing 2-in. round opening, not less than 82 per cent nor more than 95 per cent.

Passing ½-in. round opening, not less than 15 per cent nor more than 25 per cent.

Passing ¼-in. sieve, not more than 5 per cent.

7. Crushed rock shall consist of particles of rock produced by quarrying and crushing ledge rock, field boulders, or pebbles, from which, after crushing, all dust and pieces below one-quarter (1/4)-inch size have been screened out. Crushed rock shall conform in quality to the specifications under "Coarse Aggregate."

8. Pebbles (gravel) shall consist of loose material containing only particles retained upon a 1/4-in. sieve, resulting from the natural crushing and erosion of rocks. Pebbles must have wearing qualities at least equal to crushed stone. Pebbles shall conform in quality to the specifications under "Coarse Aggregate."

9. Air-cooled blast-furnace slag—The broken slag shall consist of roughly cubical fragments of air-cooled blast-furnace slag, reasonably uniform in density and quality and reasonably free from metallic iron, containing no dirt or other objectionable matter. The slag shall weigh not less than seventy (70) pound per cu. ft.

10. Chatts, or tailings, are terms locally applied to by-products, or waste products, of certain mining and industrial operations. When used as coarse aggregate for concrete pavements, such materials shall substantially conform to the specifications under "Coarse Aggregate."

11. (*c*) *Mixed Aggregate.*—Mixed aggregate shall consist of a combination of fine and coarse aggregates. That portion of mixed aggregate passing a one-quarter (1/4)-inch sieve shall conform to the requirements for fine aggregate; and that portion of mixed aggregate retained on a one-quarter (1/4)-inch sieve shall conform to the requirements for coarse aggregate.

(C) Water

12. Water shall be clean, free from oil, acid, alkali, or vegetable matter.

(D) Reinforcement

13. Reinforcement shall consist of steel fabric, or of steel bars, or a combination of both, and shall have an effective weight exclusive of dowel bars at joints and of circumferential bars of at least . . . . . . lb. per 100 sq. ft.

14. (*a*) *Steel Fabric.*—Steel fabric shall be manufactured from cold-drawn wire, and shall comply with tentative standards of the American Society for Testing Materials, Serial Designation A 82–21 T.

15. The spacing of primary members shall be not more than . . . . . . in., and of secondary members not more than . . . . . . in.

16. (*b*) *Steel Bar Reinforcement.*—This style of reinforcement shall consist of steel bars of the size, shape, and spacing shown on the plans, and shall be properly formed into mats. All intersections of longitudinal and transverse bars along the exterior edges of the mat and every other intersection of the longitudinal and transverse bars in the interior of the mat shall be securely wired or clipped together to resist displacement during handling and concreting operations. The materials shall have an effective weight of not less than . . . . . . lb. per 100 sq. ft., exclusive of laps, ties, clamps, chairs, and such portions of the bars as are not in the plane of the mat for their full lengths.

17. Steel bars shall comply with the standard requirements for concrete reinforcement bars, structural and intermediate grades, of the American Society for Testing Materials, Serial Designation A 15–14. All bar reinforcement, when placed in the pavement, shall be free from excess rust, scale or other substance which prevents the bonding of the concrete to the reinforcement. When in storage on the work, bars shall be protected from corrosion by placing them on a dry platform under a weatherproof cover.

(E) Joint Filler

18. Joint filler shall consist of prepared strips of fiber matrix and bitumen, containing not more than 25 per cent of inert material, having thickness of ...... in., and width equal to ...... in. greater than the thickness of the pavement at any point. The bitumen used in manufacture of the joint filler may be either tar or asphalt of a grade that will not become soft enough to flow in hot weather, nor brittle in cold weather. The prepared strips shall be cut to conform to the cross-section of the pavement and in lengths equal to the width of the pavement, except that strips equal in length to half the width of the pavement may be used when laced or clipped together at the center in a workmanlike and effective manner.

(F) Shoulders

19. (Any special materials for the construction of shoulders should be here described as desired by the engineer.)

III. SUBGRADE

20. Subgrade will be considered as that portion of the highway upon which the pavement is to be placed.

(A) Fine Grading

21. Fine grading will include the finished excavation and embankment which may be necessary to bring the subgrade to the required elevation, alignment, and cross-section. All suitable materials removed from the excavation in fine grading shall be used as far as practicable in the formation of the embankment, as may be required. Such material not used in embankment may be deposited on the shoulders as directed by the engineer. When the amount of the embankment exceeds the amount of the material available from excavation, suitable material shall be obtained by the contractor from borrow pits located beyond the limits of the shoulders or embankment slopes. Such borrow pits shall be left in neat condition, such as will drain completely. Ditch sections and back slopes of cuts must conform to the plans, and be left with neat and uniform appearance.

(B) Preparation and Maintenance

22. The subgrade shall be constructed to have, as nearly as practicable, a uniform density throughout its entire width. Wherever the subgrade

extends beyond the lateral limits of an old roadway, or wherever an old gravel, macadam, or other hard, compared crust comes within 6 in. of the elevation of the finished subgrade, such old roadway or crust shall be ploughed, loosened, or scarified to a depth of at least 6 in., and the loosened material redistributed across the full width of the subgrade, adding suitable material, when necessary, so that when compacted to the required elevation, alignment, and cross-section, the subgrade will approach, as nearly as possible, a condition of uniform density. Compression of the subgrade material shall be accomplished with a self-propelled roller weighing not less than 3 tons. Hand-tamping portions of the subgrade may be directed by the engineer when necessary. There shall not be left on the subgrade or shoulders, berms or ridges of earth or other material that will interfere with the immediate discharge of water from the subgrade to the side ditches, and the subgrade shall be maintained free from ruts so that it will, at all times, drain properly.

23. All depressions developing under traffic on the subgrade, or in connection with rolling, shall be filled with suitable material. Rolling shall be continued until the subgrade is uniformly compacted, properly shaped, and true to grade and alignment. It is not intended that the rolling shall be continued beyond this point, as the purpose of rolling is not to produce a subgrade that cannot be further compacted, but to produce a uniformly compacted subgrade. All hauling shall be distributed over the width of the subgrade so far as practicable, so as to leave it in a uniformly compacted condition.

24. After being prepared in the above manner, the subgrade shall be so maintained until the concrete pavement has been placed thereon.

(C) Checking and Acceptance

25. Immediately prior to placing concrete pavement on the subgrade, it shall be checked by means of an approved scratch template, resting on the side forms, having the scratch points placed not less than 8 in. apart, and to the exact elevation and cross-section for the subgrade surface. The scratch template shall be drawn along the forms so that the plane of the points will be at a right angle to the grade line, and the long axis of the template at a right angle to the center line of the pavement. All high places indicated by the scratch points shall be removed to trude grade, and any low places back filled with suitable material, and rolled or hand-tamped until smooth and firm. The subgrade shall be checked and completed in accordance with these requirements for a distance of not less than 100 ft. in advance of the concrete. If hauling over the subgrade after it has been finished and checked as above specified results in ruts or other objectionable irregularities, the contractor shall reroll or hand-tamp the subgrade and place it in smooth and satisfactory condition before the pavement is deposited upon it. If the condition of the subgrade is such that it cannot be placed in satisfactory condition to receive the pavement by the above methods, placing pavement may be stopped by the engineer, unless the contractor can provide and haul over suitable trackways or use other satisfactory means for the protection and maintenance of the subgrade.

(D) Special Treatment

26. (Special treatment may be specified for certain subgrades such as sand, gumbo, adobe, and other materials, which cannot be satisfactorily prepared for pavement by the methods specified in the foregoing paragraphs.)

IV. FORMS

(A) Materials

27. Wooden forms shall be dressed to 3-in. thickness, and equal in depth to the thickness of the pavement at the sides. Forms shall rest upon stakes driven into the ground within 1 ft. of each end of each separate piece, and at intervals not greater than 5 ft. elsewhere. Forms shall be held by stakes driven into the ground along the outside edge at intervals of not more than 6 ft., two stakes being placed at each joint. The forms shall be firmly nailed to the side stakes, and firmly braced at any point where necessary to resist the pressure of the concrete or the impact of the tamper. Forms shall be capped along the inside upper edge with 2-in. angle irons.

28. Metal forms shall be of shaped steel sections not less than 10 ft. in length, for tangents and for curves having radii of 150 ft. and over. For curves of less radii, sections 5 ft. long may be used. Forms must have a depth equal to the side thickness of the pavement. Forms shall be made of steel plate of approved section. At least three bracing pins or stakes shall be used to each 10 ft. of form, and the bracing and support must be ample to resist the pressure of the concrete and the impact of the tamper without springing.

(B) Setting

29. Forms shall be set to exact grade and alignment at least 500 ft. in advance of the point of depositing concrete. Before setting, the sections must be thoroughly cleaned. After setting, they shall be thoroughly oiled before concrete is placed against them. Forms in place will be subject to check and correlation of line or grade at any time.

V. PAVEMENT SECTION

30. Width, thickness, and crown of concrete pavement shall be as shown on the plans for the improvement.

VI. JOINTS

31. The joints to be formed shall be transverse or longitudinal. They shall be tested during and after finishing with a 10-ft. straightedge, and any irregularities in the surface shall be immediately corrected. Expansion joints shall be formed between the pavement under construction, and all other rigid types of pavement or structures to which it may be adjacent. All joints shall be edged to a radius of $\frac{1}{8}$ in. Joints shall be made as follows:

(A) Transverse Expansion Joints

32. Transverse expansion joints shall be .... in. wide, spaced .... ft. apart. A bulkhead cut to the exact cross-section of the

pavement shall be securely staked in place at right angles to the center line and surface of the pavement. The premolded joint filler shall be placed against the bulkhead and held in position by pins on which there is an outstanding lug. Concrete shall be deposited on both sides of the bulkhead before it is removed. After the concrete has been struck off, the bulkhead shall be removed by lifting it slowly from one end and replacing it with concrete as it is lifted, so that the joint filler will be left in the correct position.

33. When expansion joints are made at the end of the day's work, they shall be formed by finishing the concrete to the bulkhead, placed as before specified. When work is resumed, the joint filler shall be placed against the hardened concrete, and held in position by pins until fresh concrete is placed against it.

34. In pavements with integral curb, the joint shall be continuous in a straight line through pavement and curb.

35. Joints shall be opened on the edges for their entire depth, upon removal of the forms.

36. Before the pavement is opened to traffic the joint filler shall be trimmed off to a uniform height of $\frac{1}{4}$ in. above the surface of the pavement.

(B) Longitudinal Expansion Joints

37. Longitudinal expansion joints shall be formed by placing the filler against the form, bulkhead, curb, or adjacent structure and placing the concrete against it. The filler shall extend the full depth of the pavement, and be flush with the pavement surface.

(C) Transverse Construction Joints

38. Transverse construction joints shall be formed whenever it is necessary to stop concreting for 30 min. or longer, except at expansion joints, by staking in place a bulkhead, as specified for transverse expansion joints, and finishing the concrete to the bulkhead. An edging tool shall be used along the bulkhead to make the construction joint a regular and well-defined line. When the plans require steel dowels across transverse joints in this bulkhead there shall be holes spaced 3 ft., center to center, 3 in. below the surface of the finished pavement, through which $\frac{3}{4}$-in. plain round steel rods 4 ft. long shall be inserted with 2 ft. projecting. At least one-half length of each bar shall be encased in heavy paper or coated with paint or oil in such a manner as to prevent a bond between the steel and the concrete.

39. When work is resumed, the plank shall be removed, care being taken not to disturb the rods or the concrete. The fresh concrete shall be placed directly against the face of the concrete previously laid and carefully worked around the rods.

40. If concreting must be stopped within 10 ft. of a previously made transverse joint, the concrete shall be removed to this joint.

(D) Longitudinal Construction Joints

41. Longitudinal construction joints shall be formed where required, and must be straight and vertical. When so indicated on the plans, steel dowles shall be used as provided in the preceding section.

VII. WATER SUPPLY

(A) Equipment

42. Where necessary for the supply of water for all operations described in these specifications, duplicate pumps, connected to an adequate pipe line along the improvement, shall be provided by the contractor. The pipe line must be fitted with drains at the low points, and air relief valves at the high points, and with convenient outlets for all paving operations. Where the concrete mixer operates on the subgrade, the pipe line shall have a minimum diameter of 2 in. For supplying a mixer using more than 4 sacks of cement per batch, 60 per cent of the pipe line shall have a minimum diameter of 3 in., and the remaining 40 per cent shall have a minimum diameter of 2 in. The large diameter pipe shall lead from the pump.

(B) Priority to Water Supply

43. The concrete pavement in place, for 10 days after laying, and the subgrade preparation, shall have prior rights to the water supply. If it should develop there is not sufficient water for all purposes, the concrete mixer shall be shut down until the water needs of the curing and subgrading operations have been cared for.

VIII. PROPORTIONING AND MIXING CONCRETE

(A) Proportioning

44. (*a*) *Measuring Materials.*—The method of measuring materials for the concrete, including water, shall be such as to insure the required proportions of each of the materials as directed by these specifications. One sack of portland cement (94 lb. net) shall be considered 1 cu. ft.

45. (*b*) *Proportions.*—The concrete shall be proportioned 1 sack of portland cement, not more than ....cu. ft. of fine aggregate, and not more than .... cu. ft. of coarse aggregate. A cu. yd. of concrete in place, measured between neat lines, must contain .... barrels of portland cement. The engineer shall compare the calculated amount of cement required by these specifications with the amounts actually used in each section of concrete .... ft. long, or between successive transverse joints. If the amount of cement actually used in the pavement varies from the specified amount by more than 3 per cent for any section, the engineer may require the proportions of the concrete to be adjusted so as to use the specified amount of cement. If it is found that the amount of cement used in any section is 92½ per cent, or less, of the specified quantity, the contractor shall be required to remove such section or sections, and replace them with concrete made in accordance with these specifications. Such removal and replacement shall be done at the expense of the contractor.

(B) Mixing

46. (*a*) *Operation of Mixer.*—The concrete shall be mixed in a batch mixer, with the "boom and bucket" type of delivery. The capacity of the drum

shall be such that only whole bags of cement are used in each batch. Mixing shall continue for at least 1 min. after all materials, including water, are placed in the drum, and before any part of the batch is discharged. The drum shall be revolved not less than 14 nor more than 18 revolutions per minute. The drum shall be completely emptied before receiving materials for the succeeding batch. The volume of the mixed material in each batch shall not exceed the mixer manufacturer's rated capacity of the drum.

47. The mixer shall be provided with a water measuring tank into which mixing water shall be discharged, having a visible gage so that the amount of water for each batch may be separately and accurately measured. The mixer shall be provided with an approved batch-timing device, which will automatically lock the batch-discharging device during the full mixing time and release it at the end of the mixing period. The timer device shall have a bell which will automatically ring at the end of the mixing period. This device shall be subject to inspection and adjustment by the engineer at any time.

48. (*b*) *Retempering.*—Mortar or concrete which has partially set shall not be retempered by being mixed with additional materials or water.

49. (*c*) *Central Mixing Plants.*—The use of central mixing plants and the transportation of mixed concrete is permitted under these specifications, provided there is no segregation of the mixed concrete, when it is delivered at the point where it is to be deposited in the pavement. The period between mixing and placing in the pavement shall not exceed 40 min., and this period may be reduced at the direction of the engineer. The concrete must be of workable consistency when placed on the subgrade.

50. (*d*) *Consistency.*—The concrete mixture shall contain no more water than is necessary to produce a workable mass which can be brought to a satisfactory finish in the pavement. The amount of water used shall not exceed 6¼ gal. per sack of cement, when the aggregates are dry.

IX. PLACING CONCRETE AND REINFORCEMENT

(A) Inspection of Subgrade

51. (*a*) *Rechecking Subgrade.*—Immediately before placing concrete, or any type of reinforcement, the subgrade shall be rechecked by means of a scratch template as provided in paragraph 25 of these specifications, and any inequalities corrected as therein provided.

52. (*b*) *Condition of Subgrade.*—Concrete shall be placed only on a moist subgrade, but there shall be no pools of standing water. If the subgrade is dry, it shall be sprinkled with as much water as it will absorb readily. The engineer may direct that the subgrade be sprinkled or thoroughly wet down from 12 to 36 hr. in advance of placing concrete, where such procedure may be deemed necessary.

(B) Placing Reinforcement

53. Steel fabric reinforcement of the size and weight shown on the plans shall be placed 2 in. below and parallel to the finished surface of the pavement

unless otherwise indicated. Fabric shall extend to within 2 in. of sides and ends of slabs. All laps of fabric sections shall be not less than three-fourths of the spacing of members in the direction lapped. Steel bar reinforcement shall be placed 3 in. below the finished surface of the pavement unless otherwise indicated on the plans. Transverse bars shall extend to within 2 in. of the margins of the pavement. Bar reinforcement shall be placed and securely supported in correct position before any concrete is laid. All intersections of longitudinal and transverse bars shall be securely wired or clipped together to resist displacement during concreting operations.

(C) Placing Concrete

54. The mixed concrete shall be deposited rapidly on the subgrade to the required depth and for the entire width of the pavement section, in successive batches and in a continuous operation without the use of intermediate forms or bulkheads between joints. While being placed, the concrete shall be vigorously sliced and spaded with suitable tools to prevent formation of voids or honeycomb pockets. The concrete shall be especially well spaded and tamped against the forms. When the concrete is placed in two horizontal layers to permit use of steel reinforcement, the first layer shall be roughly struck off with a template or screed, riding on the side forms, at the correct elevation to permit placing the reinforcement in specified position. The concrete above the reinforcement shall be placed within 15 min. after the first layer has been placed. Any dust, dirt, or foreign matter which collects on the first layer shall be carefully removed before the upper layer is placed.

55. Whenever the placing of concrete is to be suspended for more than 30 min., a transverse joint shall be formed, at the point directed by the engineer to close the section. Any concrete in excess of that needed to complete a section, when work is stopped for more than 30 min., shall not be used in the pavement.

(D) Finishing

56. (*a*) *General.*—Experienced and skilful workmen must be employed at all times for preparing the surface of the pavement. The concrete shall be brought to the specified contour by means of a heavy screed or template, fitted with handles, weighing not less than 15 lb. per lin. ft. This screed or template may be of steel, or of wood shod with steel. It shall be shaped to the cross-section of the pavement, and have sufficient strength to retain its shape under all working conditions. The template or screed shall rest on the side forms and shall be drawn ahead with a sawing motion. At transverse joints, the template shall be drawn not closer than 3 ft. toward the joint, and shall then be lifted and set down at the joint and drawn backwards away therefrom. Surplus concrete shall then be taken up with shovels and thrown ahead of the joint.

57. (*b*) *Belting.*—The concrete shall be finished by using a belt of wood, canvas, or rubber, not less than 6 nor more than 12 in. wide, and at least 2 ft. longer than the width of the pavement. The belt shall be applied with a combined crosswise and longitudinal motion. For the first applica-

tion, vigorous strokes at least 12 in. long shall be used, and the longitudinal movement along the pavement shall be very slight. The second application of the belt shall be immediately after the water sheen disappears, and the stroke of the belt shall be not more than 4 in. and the longitudinal movement shall be greater than for the first belting.

58. (*c*) *Machine Finishing.*—When a finishing machine is used, it shall be so designed and operated as to strike off and consolidate the concrete, eliminating ridges and producing a true and even surface. The operation of the machine shall be so controlled as to keep the coarse aggregate near the finished surface of the pavement. Repeated operation of the machine over a given area is to be avoided.

59. A hand-tamping template and belt must be kept for use in case the tamping machine breaks down.

60. (*d*) *Longitudinal Floating.*—Immediately after the screeding specified under IX (D) 56 (*a*) has been completed, the surface should be inspected for high or low spots and any needed corrections made by adding or removing concrete. Rough spots should be gone over with a long-handled float and worked to proper contour and grade. The entire surface shall then be floated longitudinally, with a float board not less than 16 ft. long and 8 in. wide. This float board shall have convenient plow handles at each end. It shall be operated by two men, one at each end, each man standing on a bridge spanning the pavement. The lower surface of the float board shall be placed upon the surface of the concrete with the long dimension parallel to the center line of the pavement. The float shall then be drawn back and forth in slow strokes about 2 ft. long, and advancing slowly from one side of the pavement to the other. The purpose of this operation is to produce a uniform, even surface on the concrete, free from transverse waves. The two bridges on which the workmen stand should be placed about 18 ft. apart when the length of the float is 16 ft. When the entire width of the pavement has been floated in this manner from one position of the bridges, they shall be moved ahead about 12 ft. so that the next section to be floated shall overlap the one previously so floated from 3 to 4 ft. After this floating has been completed, and all transverse waves eliminated, the surface shall be finished by the belting process specified in Paragraph 57.

61. (*e*) *Finishing at Joints and Tooling.*—The contractor shall provide a suitable split float or split roller, having a slot to fit over expansion joints. This device shall be so arranged as to float the surface for a width of at least 3 ft. on each side of the joint simultaneously. This device shall be used in such manner as to produce a true surface across the joint. Edges of the pavement, at joints and side, shall be tooled for a width of 2 in., the corners rounded to a radius of ¼-in.

62. (*f*) *Trueness of Surface.*—The finished surface of the pavement must conform to the grade, alignment, and contour shown on the plans. Just prior to the final finishing operation, the surface shall be tested with a light straightedge, 10 ft. in length, laid parallel to the center line of the pavement. Any deviation shall be immediately corrected.

63. The contractor shall be held responsible for the trueness of surface of the pavement, and shall be required to make good any deviation from the alignment, grade, and contour shown on the plans.

X. CURING AND PROTECTION

(A) Burlap Cover

64. The contractor shall provide a sufficient amount of burlap or canvas for every mixer on the job, to cover all of the pavement laid in any one day's maximum run. Burlap or canvas cover shall be made up in sheets 12 ft. wide, and 4 ft. longer than the width of the pavement. Burlap or canvas cover shall be placed on the concrete immediately after the final belting, and shall then be sprayed with water in such a manner that the surface of the pavement will not be damaged. Burlap or canvas cover shall be kept continuously moist by spraying until the concrete has taken final set.

(B) Wet Earth Cover

65. As soon as it can be done without damaging the concrete, the surface of the pavement shall be covered with not less than 2 in. of earth, or 6 in. of hay or straw. This cover shall be kept continuously wet by spraying for 10 days after the concrete is laid.

(C) Sprinkling or Ponding

66. The sprinkling system of curing may be used if approved by the engineer. The sprinkling equipment shall be placed carefully, and without injuring the concrete surface. The sprinkling system shall be so arranged, and supplied with sufficient water at ample pressure, to keep every portion of the pavement surface continuously wet (both night and day) for 10 days after laying the concrete. Dikes shall be constructed along both edges of the pavement, with cross-dikes where necessary, and the water flowing off the surface of the pavement shall be collected and led to the ditches or culverts as directed by the engineer. The contractor shall be held responsible for any damage to the roadway, shoulders, or adjacent property, by reason of escaping water.

67. The ponding system of curing may be used at the option of the contractor. Dikes shall be built along both edges of the pavement, with cross-dikes at sufficiently frequent intervals, and the pavement flooded with sufficient water within the dikes to keep all portions of the pavement surface continuously covered with water for 10 days after the concrete is laid.

(D) Cleaning

68. After 14 days, the earth or other cover may be removed. After 30 days, the contractor may use a mormon or a fresno scraper to remove the cover, except that scrapers shall not be used within 1 ft. of expansion joints. Cover within 1 ft. of expansion joints must be removed by hand. Road

machines, or blade graders of the 2- or 4-wheel type shall not be used for removing the cover.

69. After the cover has been removed, or ponds emptied and dikes removed, the entire surface of the pavement shall be swept clean and free from dirt and debris. Horse- or motor-drawn sweepers shall not be operated on the pavement till 30 days have elapsed after the concrete is placed.

(E) Cold Weather Protection

70. Concrete shall not be mixed nor deposited when the temperature is below freezing, except under such conditions as the engineer may direct in writing. If, at any time during the progress of the work, the temperature is, or in the opinion of the engineer, will, within 24 hr., drop to 38° F. the water and aggregates shall be heated, and precautions taken to protect the concrete from freezing until it is at least 10 days old. In no case shall concrete be deposited upon a frozen subgrade, nor shall frozen materials be used in the concrete.

XI. PROHIBITION OF TRAFFIC

(A) Barricades

71. The contractor shall provide and maintain substantial barricades across the pavement, with suitable warning signs by day and by night, to prevent traffic of any kind upon the pavement before it is 21 days old, or before the cover has been removed. The contractor shall provide and maintain watchmen at each mixer, whenever the paving crew is not at work, who shall prevent destruction or removal of barricades, and keep traffic off the pavement.

72. No section of pavement shall be opened to traffic until written instructions have been given by the engineer.

(B) Crossings

73. At public highway and private crossings, the contractor shall provide suitable structures to carry the traffic across the pavement without injury to the concrete. All such structures shall be subject to the approval of the engineer, and he may direct their improvement, or repair, as conditions may require.

XII. CONDITION BEFORE ACCEPTANCE

74. Before the road will be considered completed in accordance with these specifications, and acceptable to the engineer, the pavement, shoulders, ditches, back slopes, and structures, shall be placed in a neat and orderly condition, conforming to the plans and specifications in all respects. Equipment, surplus materials, and construction debris of every description shall be removed from the right of way.

TWO-COURSE PORTLAND CEMENT CONCRETE PAVEMENT FOR HIGHWAYS

I. GENERAL

1. It is the intent of these specifications to cover the requirements for the materials and construction of Portland Cement Concrete Highway Pavements composed of two layers of concrete made with unlike coarse aggregates, but of the same proportions.

II. MATERIAL

2. The requirements for

(A) Cement,

(B) Aggregates,

(*a*) Fine aggregates,

shall be as specified in Sec. II, (A), (B) and (*a*) one-course concrete highway pavement.

3. (*b*) *Coarse Aggregate for Bottom Course.*—Structurally sound material considered too soft for a pavement surface may be used as the coarse aggregate in the bottom course. It shall consist of crushed rock, pebbles (gravel), air-cooled blast-burnace slag, chatts, or tailings. The particles of coarse aggregate shall be of clean, durable material, free from vegetable or other deleterious substances, and shall contain no flat or elongated pieces.

(Note: In many cases it will be necessary for the engineer to specify the sizes, grading, and quality of coarse aggregate in accordance with local conditions. In every case, the engineer should provide specifications which will require the use of the best coarse aggregate, which is economically available. The following specifications covering size and grading of coarse aggregate will be found applicable in most sections of the country and are intended for use with proportions from 1:2:4 to 1:1½:3.)

4. The size of the coarse aggregate shall be such as to pass a 3-in. round opening. Coarse aggregate shall be uniformly graded within the limits shown in the following table, and any material which does not come within the limits specified shall be rejected.

Passing 3-in. round opening, 100 per cent.

Passing 2-in. round opening, not less than 82 per cent nor more than 95 per cent.

Passing ½-in. round opening, not less than 15 per cent nor more than 25 per cent.

Passing ¼-in. sieve, not more than 5 per cent.

5. (*c*) *Coarse aggregate for top course* shall consist of crushed rock, pebbles (gravel), air-cooled blast-furnace slag, chatts, or tailings. The particles of coarse aggregate shall be of clean, hard, tough, durable material, free from vegetable or other deleterious substances, and shall contain no soft or elongated pieces. The crushed rock shall wear not more than 6 per cent when subjected to the standard Deval abrasion test. When subjected to the abrasion test described on page 30, U. S. Department of Agriculture, *Bulletin* 555, pebbles shall show a loss of not more than 12 per cent.

6. The size of the particles shall be such that at least 95 per cent shall pass a 1-in. round opening and not more than 5 per cent shall pass a 1/4-in. sieve, with all the intermediate sizes retained.

7. The requirements for

Crushed rock,

Pebbles (gravel),

Air-cooled blast furnace slag,

Chatts, or tailings,

(*d*) Mixed aggregates,

shall be as specified in Sec. II (B) one-course concrete highway pavement.

8. The requirements for

(C) Water,

(D) Reinforcement,

(E) Joint filler,

(F) Shoulders,

shall be as specified in Sec. II, (C), (D), (E), (F), one-course concrete highway pavement.

III. SUBGRADE

9. The requirements for subgrade shall be as specified in Sec. III, one-course concrete highway pavement.

IV. FORMS

10. The requirements for forms shall be as specified in Sec. IV, one-course concrete highway pavement.

V. PAVEMENT SECTION

11. Width and thickness of concrete pavement and the depth of the top and bottom courses shall be as shown on the plans for the improvement.

VI. JOINTS

12. The requirements for joints shall be as specified in Sec. VI, of one-course concrete highway pavement.

VII. WATER SUPPLY

13. The requirements for water supply shall be as specified in Sec. VII, of one-course concrete highway pavement.

VIII. PROPORTIONING AND MIXING CONCRETE

14. (*a*) *Measuring Materials.*—The method of measuring the materials for the concrete, including water, shall be such as to insure the required proportions of each of the materials as directed by these specifications. One sack of portland cement (94 lb. net) shall be considered 1 cu. ft.

15. (*b*) *Proportions.*—The concrete in both the top and bottom course shall be proportioned 1 sack of portland cement, not more than .... cu. ft. of fine aggregate, and not more than .... cu. ft. of coarse

aggregate. A cubic yard of concrete in place, measured between neat lines must contain............ barrels of portland cement. The engineer shall compare the calculated amount of cement required by these specifications with the amounts actually used in each section of concrete............ft. long, or between successive transverse joints. If the amount of cement actually used in the pavement varies from the specified amount by more than 3 per cent for any section, the engineer may require the proportions of the concrete to be adjusted so as to use the specified amount of cement. If it is found that the amount of cement used in any section is 92½ per cent or less, of the specified quantity, the contractor shall be required to remove such section or sections, and replace them with concrete made in accordance with these specifications. Such removal and replacement shall be done at the expense of the contractor.

16. The contractor may, at his option, construct the top course of mortar composed of cement and fine aggregate mixed in the proportion of 1 sack of cement to............cu. ft. of fine aggregate.

17. The requirements for

(B) Mixing,
(*a*) Operation of mixer,
(*b*) Retempering,
(*c*) Central mixing plants,
(*d*) Consistency,

shall be such as specified in Sec. VIII, (B), (*a*), (*b*), (*c*), (*d*), one-course concrete highway pavement.

IX. PLACING CONCRETE AND REINFORCEMENT

18. The requirements for

(A) Inspection of Subgrade,

shall be as specified in Sec. IX, (A), one-course concrete highway pavement.

(B) Placing Reinforcement

19. Steel fabric reinforcement of the size and weight shown on the plans shall be placed between the bottom and top courses, unless otherwise indicated. Fabric shall extend to within 2 in. of sides and ends of slabs. All laps of fabric sections shall be not less than the spacing of members in the direction lapped. Steel bar reinforcement shall be placed between the top and bottom courses unless otherwise indicated on the plans. Transverse bars shall extend to within 3 in. of the margins of the pavement. Bar reinforcement shall be placed and securely supported in correct position before any concrete is laid. All intersections of longitudinal and transverse bars shall be securely wired or clipped together to resist displacement during concreting operations.

(C) Placing Concrete

20. The mixed concrete shall be deposited rapidly on the subgrade to the required depth and for the entire width between longitudinal joints, without

the use of intermediate forms or bulkheads between joints. While being placed, the concrete shall be vigorously sliced and spaded with suitable tools, to eliminate voids or honeycomb pockets. The concrete shall be especially well spaded and tamped adjacent to forms, bulkheads, and curbs. The bottom course shall be struck off at the correct elevation with a template or screed riding on the side forms. The top course shall be placed within 15 min. after the bottom course was placed. Any dust, dirt, or foreign matter which collects on the surface of the bottom course shall be carefully removed before the top course is placed.

21. Whenever, because of a breakdown or for any other reason, operations will be stopped for more than 30 min., a transverse joint shall be formed at the point directed by the engineer, to close the section. Both the top and bottom courses shall be completed to this joint. Any concrete in excess of that needed to complete a section, when work is stopped for more than 30 min., shall not be used in the pavement.

22. The requirements for

(D) Finishing

shall be as specified in Sec. IX, (D), of specifications for one-course concrete highway pavement.

X. CURING AND PROTECTION

23. The requirements for curing and protection shall be as specified in Sec. X, of specifications for one-course concrete highway pavement.

XI. PROHIBITION OF TRAFFIC

24. The requirements for prohibition of traffic shall be as specified in Sec. XI, of specifications for one-course concrete highway pavement.

XII. CONDITION BEFORE ACCEPTANCE

25. The Condition before Acceptance shall be as specified in Sec. XII, of specifications for one-course concrete highway pavement.

INDEX

A

Aggregates (*See also* Fine aggregates, Coarse aggregates, and Sand).
  definition, 1
  inspection, 188
  sampling, 188
  sieve analysis curves, 191
  tests of bulking effect of water, 195
    colorimetric test, 194
    sieve analysis, 190
    silt in fine aggregate, 193
    standard method of test, organic impurities, 323
      sieve analysis, 320
      unit weights, 319
    tentative method of tests, decantation test, 322
  unit weights, 189
  voids, 191
Appendices, 303
Aspdin, Joseph, 3

B

Basement (*See* Concrete basement).
Bridges (*See* Reinforced concrete bridges).
Briquettes, dimensions, 317
  molds, 317
Buckets, drop bottom, 70
Building units (*See* Concrete building units).
Buildings (*See* Reinforced concrete buildings).

C

Cement, 1
  (*Also see* Portland cement).
Cement mortars (*See* Portland cement mortars).
  tests (*See* Portland cement tests).
Cementing materials, 2
  classification, 2
Coarse aggregates, 12
  (*Also see* Aggregates).
  bulking effect of water, 14
  definition of, 1
  fineness modulus, 15
  inspection, 13
  kinds, 12
  sieve analysis, 15
  specific gravity, 14
  specifications, 15, 130
  unit weight, 14
  voids, 14
Concrete (Portland cement concrete), bonding new to old, 67
  consistency, 47
    tentative method of test for consistency, 329
  definition, 1
  depositing in forms, 66
  effect of various oils and liquids on concrete and protective treatment required, 339
  effect of various substances in concrete mixes, 23
  effect of various substances on hardened concrete, 25
  estimating, 154
  materials (*See* Aggregates).
    computing quantities, 49
    measuring, 48
      by volume, 48
      by weight, 49
      inundation method, 48
    tests required for, 212

Concrete mixers, 55
mixing, by hand, 51
by machine, 55
specifications for, 57
placing during freezing weather, 70
placing under water, 69
properties, 17
abrasion, 22
absorption, 22
compressive strength, 17
contraction, 22
expansion, 22
slump, 19
unit weight, 22
workability, 19
proportioning, 26
by arbitrary proportions, 28, 199
by Joint Committee table, 33, 200, 324
by sieve analysis and maximum density curve, 30
by surface area method, 32
by voids, 29
by water-cement ratio and slump, 35, 202
by water-cement ratio, slump, and fineness modulus, 38, 204
general rules and theory, 26
illustrative example, 43
protection in freezing weather, 72
protection while hardening, 68
slump, 37
test specimens—making and storing in field, 335
testing machines used, 213
tests, consistency or slump, 198
effect of age, 211
effect of varying amount of mixing water, 205
effect of varying fineness modulus, 207
required for concrete materials, 212
standard methods of making compressive tests, 330
Concrete tests, tentative method of making consistency test, 329
transportation, 61
barrows, 61
booms, 63
buckets, 65
carts, 61
towers, 61
waterproofing, by adding integral compounds, 74
by proper proportioning, 73
by water proof coatings and membranes, 75
Concrete aggregates (*See* Aggregates).
Concrete arches (*See* Reinforced concrete arches).
Concrete basement, concreting, 231
estimating, 225
excavation, 227
forms, 229
removal of forms, 232
staking out, 223
Concrete block (*See* Concrete building units).
Concrete brick (*See* Concrete building units).
Concrete bridges (*See* Reinforced concrete bridges).
Concrete building units, block, brick, and tile manufacture, 106, 298
curing, 108
dry tamp method, 107
pressure method, 108
wet cast method, 108
Concrete building units, block, brick, and tile specifications, 110, 342
block walls, laying, 299
pointing, 302
Concrete culverts, 275
concreting, 282
estimating, 275
excavation, 280
forms, 281
placing reinforcement, 281
removing forms, 283
specifications, 275

Concrete culverts, staking out, 280
types, 275
water area required, 276
Concrete cylinder molds, 336
Concrete floors, 271
specifications, 272
one course, 274
two course, 273
Concrete forms (*See* Forms).
Concrete ornamental stone, 110
Concrete pavements, 245
crew organization, 252
curing, 259
design, 245
estimating, 245
forms, 251
mixing, 255
placing concrete, 255
plant, 252
proportions, 255
specifications, 245
standard specifications, 346
one course pavement, 346
two course pavement, 359
subgrade, 251
Concrete plant, 58
for arched bridges, 297
for paving, 252
for slab and girder bridges, 292
Concrete septic tanks, 263
Concrete sidewalks, 233
base, 234
concreting, 236
curing, 236
estimating, 233
finishing, 236
forms, 234
grade, 234
location, 234
specifications, 233
Concrete steps, 267
Concrete surface finish (*See* Surface finishing), 96, 101, 161
estimating, 161
granolithic, 102
mechanical finishing, 96
terrazo, 102
Concrete surface finish, wearing surface, 101
Concrete tile (*See* Concrete building units).
Concrete trim stone, 110
Concrete wearing surfaces, 101
granolithic, 102
preparation, 101
terrazo, 102
Concrete window sills and lintels, 269
dimensions, 270
forms, 270
mix, 271
reinforcement, 270
Consistency of concrete, 46
(*See* Concrete consistency).
Contracts, 115
definition, 115
kinds, 115
standard bridge contract, 116
bond, 117
contract, 119
proposal, 120
Culverts, 275
(*See* Concrete culverts).
Curbs and gutters, 241
(*See* Concrete curbs and gutters).

E

Estimating, 143–179
building costs (square and cube methods), 166
concrete basement, 225
concrete culverts, 280
concrete (materials, labor and costs), 154
concrete pavements, 245
concrete sidewalks, 233
concrete surface finish, 161
excavation, 145
forms, 151
in general, 143
miscellaneous items, 163

Estimating miscellaneous items (block masonry, brick work, flooring, flashing, glass and glazing, heating, lighting, plastering, plumbing, roofing, sash, stucco)
reinforcing steel, 158
sample cost estimate, 172
sample quantity estimate, 168
Excavation, basement, 227
culverts, 280
estimating, 145

F

Field work, 218
(For list of field jobs see table of contents).
inspection of, 218
supervision of, 220
Fine aggregates (*Also see* Aggregates).
definition, 1
fineness modulus, 10
general, 8
sand, 8
bulking effect of water, 9
grading, 9
Ottawa, 10
sieve analysis, 10
silt test, 9
voids, 9
screenings, 11
specifications, 11, 129
Fineness modulus (*See also* Aggregates, Fine aggregates and Coarse aggregates).
of aggregates, 38
of coarse aggregates, 15
of fine aggregates, 10
maximum practical values, 39
Finishing concrete surfaces, 96
(*See* Concrete surface finishing).
Floors (*See* Concrete floors).
Forms, depositing concrete in, 66
estimating, 151
for arch bridges, 293
for basements, 229, 232
Forms for buildings, 286
for culverts, 281
for girder bridges, 290
for pavements, 251
for septic tanks, 266
for sidewalks, 234
for slab bridges, 290
for steps, 268
for window sills and lintels, 270
in general, 77
metal, 91–95
Blaw, 92
Flore tyles, 95
Floredomes, 95
Metaforms, 93
Meyer, 95
steel craft, 92
wall, 91
removal of form marks, 96
specifications, 134
wooden, column forms, 88
cost, 77
erection, 79
floor forms, 90
lumber sizes, 78
nails, 78
removal of, 80
rules for, 78
ties, 83
wall forms, 81

G

Gillmore needles, 316
Girder bridges (*See* Reinforced concrete bridges).
Gravel, 13
(*See* Aggregate and Coarse aggregate).
Gypsum plaster, 2

H

Hand mixing of concrete, 51
Hydraulic cement, 2
Hydraulic lime, 2

I

Inspection of aggregates, 188
  concrete work, 218
  portland cement, 183

L

Laboratory (*See* Table of contents for list of laboratory jobs).
  methods, 180
  reports, 181
  work, 180
Le Chatelier apparatus, 308
Lime, 2
Lintels, 269
  (*See* Concrete window sills and Lintels).

M

Machine mixing of concrete, 55
Measuring concrete materials, 48
Mixers, 55
Mixing concrete (*See* Concrete).
Mortars (*See* Portland cement mortars).

N

Natural cement, 2

O

Ottawa sand, 10

P

Parker, James, 3
Pavements (*See* Concrete pavements).
Plans, 137
  abbreviations used, 138
  complete plans, 137
  reading plans and blueprints, 138
  standard plans for concrete highway bridge, 139
Plant (*See* Concrete plant).
Plasters (gypsum), 2
Portland cement, 3
  history, 3
  inspection, 183
  manufacture, 4
    dry process, 5
    quantity, 4
    raw materials, 4
    wet process, 5
  properties, 5
    fineness, 6
    set, 6
    soundness, 6
    specific gravity, 7
    strength, 6
  standard specifications, 303
  standard tests, 184, 303
Portland cement concrete (*See* Concrete).
Portland cement mortars, 7
  properties, 8
    strength, 8
    weight, 8
  proportioning, 7
  tests, 196
Progress charts and reports, 175
Properties of concrete (*See* Concrete properties).
Proportioning of concrete mixes (*See* Concrete proportioning).
Puzzolanic cement, 2

R

Roman cement, 3
Reinforced concrete bridges, arches, 293
  centering, 293
  forms, 293
  plant, 297
  pouring, 298
Reinforced concrete bridges, slab and girder bridges, 283
  excavation, 283, 290
  forms, 286, 290
  foundations, 283

Reinforced concrete bridges, slab and girder bridges, placing steel, 286
  planning construction, 283
  plans, 286
  plant, 292
  pouring, 288
Reinforcing steel (estimating), 158

S

Sand (*See* Aggregates and fine aggregates).
  Ottawa, 10
  standard test for organic impurities, 323
  tentative decantation test, 322
Saylor, David O., 3
Screenings, 11
Septic tanks (*See* Concrete septic tanks), 263
Sidewalks (*See* Concrete sidewalks).
Sieve analysis (*See* Aggregates, Fine aggregates, Coarse aggregates and Sand).
  coarse aggregates, 15
  curves, 191
  fine aggregates, 10
  sand, 10
  test methods, 320
Sieves (specifications and sizes), 321
Slab bridges (*See* Reinforced concrete bridges).
Slag (*See* Aggregates and coarse aggregates).
Slag cement, 2
Slump of concrete, 37
  test, 47, 329
  test apparatus, 329
Smeaton, John, 3
Specifications, coarse aggregate, 15, 130
  concrete brick, 344
  concrete building block and tile, 342
  concrete curbs and gutters, 244
  concrete floors, 272
  concrete pavements, 245, 346
Specifications, concrete sidewalks, 233
  detailed, 121
  fine aggregate, 11, 129
  forms, 134
  general, 120
  mixing concrete, 57
  proportions for concrete, 324
  reinforced concrete highway bridge, 122
  standard (*See* Appendices).
    concrete brick, 344
    concrete building block and tile, 342
    method of test for making and storing concrete specimens, 335
      making compressive tests of concrete, 330
      organic impurities in sand, 323
      sieve analyses, 320
      unit weights of aggregates, 319
    portland cement, 346
  surface finishing, 135
  tentative (*See* Appendices).
    method of test for consistency of concrete, 329
      decantation test for fine aggregates, 322
Standard Ottawa sand, 10
Steel forms (*See* Forms).
Surface finishing (*See* Concrete surface finish).
  concrete floors, 271
  concrete pavements, 257
  concrete sidewalks, 236
  estimating, 161
  mechanical, 96
    rubbing, 99
    sand blast, 99
    sand float, 99
    scrubbing, 99
    tooling, 99
    washing, 99
  specifications, 135

Surface finishing, use of colored aggregates, 100
use of pigments, 100

T

Testing machines, 213
Tests (*See* Various headings).
required for concrete materials, 212
Time and work schedules, 173
Transportation of concrete (*See* Concrete), 61
Tremie, 69

V

Vicat apparatus, 311
Voids in coarse aggregates, 14
sand, 9

W

Walls (rules for laying concrete, block walls), 299
Water, bulking effect on sand, 9
for concrete, 1, 16
Water proofing concrete by adding integral compounds, 74
applying water proof coatings and membranes, 75
proper proportioning, 73
Water-cement ratio (*See* Concrete) 35, 38
Wearing surfaces, 101
(*See* Concrete wearing surfaces).
Window sills, 269
(*See* Concrete window sills and lintels).
Wooden forms (*See* Forms).
Work and time schedules, 173
Work in the field (*See* Field work).